Surface and groundwater quality impacts of conservation tillage practices on burley tobacco production systems in Southwest Virginia

by

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Abstract

This study measured sediment, nutrient and pesticide edge-of-field and deep percolation losses from conventional tillage (CT), strip tillage (ST), and no-till (NT) treatments in a burley tobacco production system. The field experiment results show that the CT treatment yielded more total runoff, 93.6 mm, than ST and NT. Compared to the CT treatment, ST reduced the total mass loss of NO_3^- by 37 percent, NH_3 by 54 percent, PO_4^{3-} by 12 percent, TP by 65 percent and TSS by 64 percent. The NT treatment reduced the total mass of NO_3^- by 49 percent, NH_3 by 46 percent, PO_4^{3-} by 17 percent, TP by 73 percent and TSS by 77 percent. Field experiment results showed that, respectively, the ST and NT treatments yielded 77 and 82 percent less chlorpyrifos, an insecticide, mass loss in runoff compared to CT. With respect to flumetralin loss, a growth inhibitor, the NT treatment yielded 30 percent less and ST yielded 6.8 percent more flumetralin mass, compared to CT.

The percolated water results show that compared to the CT treatment, ST resulted in 33 percent less NH_3, 7.5 percent less TKN, and 39 percent less PO_4^{3-} total mass. The NT treatment yielded 41 percent less NH_3 and 20 percent less TKN total mass loss compared to the CT treatment. The NT treatment had the most NO_3^-, PO_4^{3-}, and TP mass loss below the root zone, however NT also had the most percolated water by 53 mm (838 L). The ST treatment yielded 77 percent less, and NT yielded 82 percent less chlorpyrifos mass loss compared to the CT treatment. Compared to CT, the NT treatment resulted in 30 percent less and ST yielded 7 percent more flumetralin mass in percolated water.

The GLEAMS model was used to simulate runoff, nutrient, sediment and pesticide losses from the same three tillage practices evaluated in the field experiment. The model results showed that for runoff volume, TSS, nitrogen, chlorpyrifos and flumetralin in runoff, the conventional tillage practice generated greater losses than the conservation tillage practices. Compared to the field experiment results, GLEAMS under predicted nitrogen and phosphorus in percolated water. The conservation tillage practices simulated in GLEAMS were effective in minimizing the loss of agricultural pollutants.

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Table of Contents

Table of Tables

Table of Figures

Chapter 1 Introduction

Tobacco is an intensively tilled crop. Tobacco production systems typically include two to six cultivation operations per season (Hawks and Collins, 1970). Intensive tillage can leave the soil exposed, which can accelerate erosion during runoff events. Substances dissolved and suspended in runoff can significantly affect the condition of the surrounding surface water. Nearby water bodies may need dredging as eroded sediment is deposited over time. High nitrogen (N) and phosphorous (P) concentrations in surface waters can lead to eutrophic conditions and decreased biodiversity (Biggar and Corey, 1969; Likens, 1972). Pesticides in runoff can weaken and eventually kill animal and plant life in nearby water bodies. Tobacco production systems are often located on fertile floodplains, increasing the likelihood that polluted runoff will reach bodies of water. In addition to surface water contamination, intensive tillage can increase the potential for leaching of nutrients and pesticides below the root zone due to increased infiltration. This is especially substantial because a total of 161,500 acres of United States' land were used for burley tobacco production in 2002, 8,000 of which were in Virginia (ERS, 2003).

Conventional tillage refers to the intensive tillage usually performed on a soil to prepare for a crop including plowing and field cultivation operations. An alternative to conventional tillage production systems is conservation tillage. Conservation tillage is a best management practice (BMP) that, through reduced cultivation, requires a minimum of 30% residue cover of stubble and dead vegetation present on the soil surface. In 2002, 103 million acres utilized conservation tillage practices out of 431 million acres of total cultivated land in the US (CTIC, 2003). Conservation tillage can be accomplished in several ways, including no-till and strip tillage. With no-till, the soil is only disturbed at planting. For strip tillage only the seedbed is disturbed at planting. No additional cultivation operations occur.

Crop residue cover left by conservation tillage methods increases the soil's surface roughness, slowing runoff velocity and lessening raindrop impact (Oschwald, 1973; Blough, 1990). Conservation tillage also decreases the edge of field losses of nutrients, sediments, and pesticides (Barisas et al., 1978; Wood and Worsham, 1986; Blough et al., 1990; Mostighimi et al., 1988; Stein et al., 1986). Furthermore, conservation tillage costs less than conventional tillage in terms of labor and energy (Christenson and Norris, 1983). Research evaluating the beneficial effects of conservation tillage in corn and soybean production systems is extensive. Less research has been conducted examining the water quality benefits of conservation tillage in tobacco production systems.

In addition to intensive tillage for weed control, tobacco production utilizes many pesticides to enhance leaf growth. Runoff containing large amounts of pesticide can potentially harm wildlife, livestock, and humans if it reaches a drinking or irrigation source. The insecticide chlorpyrifos (Dursban or Lorsban) and the grow regulator flumetralin (Prime Plus) were tested for in runoff and leachate samples in this study. Although no studies observe these two pesticides under different tillage practices, comparisons between other pesticides have been documented. No-till systems were found to decrease atrazine and alachlor in runoff and in leachate samples (Kenimer et al., 1987; Gish et al., 1995) on corn fields.

This study utilized the Groundwater Loading Effects of Agricultural Management Systems model (GLEAMS) to compare long-term edge-of-field losses from a tobacco production system under three conservation tillage practices. The GLEAMS model is an expansion of the widely used Chemicals, Runoff and Erosion from Agricultural Management Systems (CREAMS) model (Knisel, 1980). The GLEAMS model was used to evaluate relative differences between the simulated tillage practices. The objectives of this study were:

- To measure sediment, nutrient, and pesticide edge-of-field losses from three tillage treatments on a burley tobacco production system.
- To perform a long-term simulation with GLEAMS to evaluate the relative effectiveness of three levels of tillage in minimizing edge-of-field losses of sediment, nutrients, and pesticides.

Chapter 2 Review of Literature

2.1 Justification of Research

Eutrophication is the nutrient enrichment of water bodies that results in high biological productivity (Likens, 1972). Nitrogen and phosphorus are the limiting nutrients in algal growth. When these nutrients are present in excess, algal blooms develop. Nitrogen and phosphorus are transported to bodies of water by agricultural runoff or subsurface flow. As the algal blooms start to decay, bacterial growth increases and the dissolved oxygen in the water is consumed (Hutchinson, 1969). Aerobic life in these aquatic ecosystems suffocates. The water body becomes shallower as decayed material sinks. The water body's flow volume decreases, which limits the amount of oxygen that can be dissolved, and decreases the growth and development of larger aquatic organisms (Hutchinson, 1969). Excessive vegetation and bacteria also make water non-potable, which increases the cost of treatment (Eutrophication: Causes, Consequences, Correctives, 1969). Table 2.1 shows the levels of nitrogen and phosphorus that can accelerate eutrophic conditions in lakes.

Table 2.1. The significance of different levels of P and N in lakes (USEPA, 1982)

Phosphorus	Nitrogen	Significance
mg-P L^{-1}	mg-N L^{-1}	
0.013	0.092	problem threshold
0.13	0.92	problems likely to exist
1.3	9.2	severe problems possible

Agricultural leachate has the potential to deposit nutrients into water bodies such as rivers and lakes due to fertilizer use, intensive tillage, and natural storms or irrigation. Nitrogen, phosphorous, and sediment are the primary pollutants in agricultural runoff. The total phosphorus level is closely related to the suspended sediment level because phosphorus adsorbs to sediment particles. Soluble phosphorus and nitrates present in subsurface drainage waters may drain into water bodies such as lakes and rivers.

The EPA has set the maximum level of NO_3-N in drinking water at 10 mg/L (US EPA, 1974). Nitrate (NO_3^-) is negatively charged and therefore does not attach to soil particles; instead it leaches through the soil. If nitrate levels become high in drinking water, infants less than four months of age are susceptible to the disease methemoglobinemia, also known as blue baby syndrome (Kross et al., 1992). The nitrates in drinking water interfere with the ability of the blood to transport oxygen, thus turning a baby a blueish hue.

2.2 Tillage and Residue Cover Comparisons

To determine if a tillage method is conservation tillage, the residue cover percentage must be determined. Shelton et al. (1997) explains the line-transect method of measuring the residue cover percentage. A measuring device, such as measuring tape or a rope with evenly spaced knots, is stretched across a section of field; this section should be representative of the entire field. The tape or rope should cross row crop rows at 45-degree angles. The residue is measured by counting the number of times a knot on the rope or a selected interval on the measuring tape is touching a piece of residue. Residue should be observed from the same side of the tape or rope. Out of 100 knots or intervals, this number is the residue cover percentage. The authors note that if less than 100 points are observed, i.e. 50, one must multiply the count by the appropriate conversion, i.e. 2, to obtain the percentage. This procedure should be repeated at least three times and an average should be reported.

Conservation tillage has been shown to reduce runoff volume and prevent nutrient and sediment movement from tobacco production systems. Wood and Worsham (1986) measured soil loss differences between no-till and conventional tillage flue-cured tobacco. Soil loss was significantly greater with the conventional tillage treatment. The total soil loss was 20 times greater in 1982 and 90 times greater in 1983 from the conventional tillage treatment.

More research has been performed with reduced tillage and varying residue cover of other crops. Barisas et al. (1978) investigated the effects of tillage practice on nutrient losses from three Iowa loam soils planted with corn. The results showed that increased residue cover did not effectively reduce the losses of water-soluble nutrients. This was due to the leaching of nutrients by residue and reduced fertilizer incorporation. The conservation tillage practices reduced nitrogen losses by controlling erosion. The study concluded that as residue cover increased, available phosphorus concentrations in the collected sediment increased. Improving fertilizer applications for conservation tillage systems may further reduce phosphorus losses.

Blough et al. (1990) researched the influence of surface storage and residue cover on runoff from slit tillage, conventional tillage and chisel tillage practices under simulated rainfall for a Letrot silt loam. The four treatments consisted of bare soil, smooth surface with 30% residue cover, 30% residue cover with slit and 50% residue cover with slit. The smooth bare soil had the highest overall runoff rate. Both treatments with 30% cover behaved similarly. A significantly greater amount of total solids was measured in the runoff from the conventional tillage treatment. Blough et al. concluded that the residue cover eliminated runoff and erosion until the slit overflowed. Runoff and erosion were significantly greater from the bare soil treatment than the other treatments.

Nitrogen loss on agricultural fields is of concern when it leaches through the soil profile in soluble nitrate form. Tyler and Thomas (1977) used pan lysimeters to measure nitrate and chloride leaching under no-till and conventional tillage corn. The research area was a Maury silt loam. The bluegrass and rye present on the no-till area was killed with paraquat and atrazine. Nitrogen as NH_4NO_3 was broadcast over the entire research area at a rate of 168 kg ha^{-1}. The leachate from June 1973 under no-till contained a total of 14.7 kg ha^{-1} nitrate; conventional tillage leachate contained 4.0 kg ha^{-1} nitrate. In June of 1974 nitrate in leachate under no-till systems was 17.9 kg ha^{-1} while conventional tillage leachate contained 6.1 kg ha^{-1}. Leachate collections in August show the opposite trend, as more nitrate was lost by conventional tillage. No-till produced an average of 200 kg ha^{-1} more corn. This study shows that conservation tillage, while preserving soil moisture, has limitations.

Residue contains nitrogen and phosphorus, which have the potential to become incorporated into the soil matrix or runoff. Miller et al. (1994) studied the leaching of nitrogen and phosphorus from three cover crop species. Combinations of freezing alone, freezing plus drying treatments and loading rate and rainfall intensity were studied. Annual ryegrass (*Lolium multiflorum* L.) leached an average of 30% of the biomass phosphorus. Between 5 and 9 % of the biomass nitrogen was leached as NO_3-N or NH_4-N from ryegrass. There was a significant difference, at the p=0.05 level, between rainfall intensities (2 cm h^{-1} vs. 4cm h^{-1}) regarding the leaching of P from ryegrass. They conclude that this study indicates only the potential for leaching P and N from cover crops.

Mostaghimi et al. (1988) studied sediment and phosphorus loss from different amounts of winter rye residue on no-till and conventional tillage on Groseclose silt loam. Phosphorus was applied at 46 kg ha^{-1}. Simulated rainfall at 50 mm h^{-1} totaled 100 mm. Soil loss and runoff volumes were reduced by no-till up to 98% and 92%, respectively. As residue amounts increased, sediment losses and runoff decreased, regardless of the tillage treatment. No-tillage yielded 5.5 times more PO_4^{3-} than conventional tillage, however sediment bound phosphorus was reduced 55%.

Stein et al. (1986) tested soil loss and runoff volume from ridge tillage and moldboard plow tillage plots with different quantities of residue cover. They concluded that the presence of residue on otherwise identical plots yielded less sediment loss. Ridge tillage did not improve erosion potential compared to conventional moldboard plow and spring disking except when residue was present. In this case, ridge tillage erosion behaved much like the conventional tillage. The authors note that erosion control was optimal with residue placement in ridge tillage furrow bottoms, which required less residue and yielded comparable sediment loss.

2.3 Pesticides

The insecticide chlorpyrifos, Dursban or Lorsban, (O, O-diethyl O-(3,5,6-trichloro-2-pyridyl) phosphorothioiate), is broadcast before transplanting to control cutworms, wireworm, flea beetles, mole crickets and root maggots on tobacco (Dow AgroSciences, 2003). Chlorpyrifos can over stimulate the nervous system causing nausea, dizziness, confusion, and at high exposures, respiratory paralysis, and death (EPA, 2000). The risk to birds, fish and mammals are high and the risk to aquatic invertebrates is very high.

The other pesticide studied was flumetralin, Prime Plus, (2-chloro-N-(2,6-dinitro-4-(trifluoromethyl)-phenyl)-N-ethyl-6-fluorobenzene-methanamine), used to prevent auxiliary buds or suckers to optimize tobacco leaf area. Flumetralin in surface waters or soils has not been found to harm humans (VDH, 1995). Flumetralin has potential to damage succeeding crops, including tobacco, due to its persistence in soil. Shelby and Fowlkes (1989) surveyed farmers in Tennessee and reported a strong correlation between flumetralin use and carryover damage to fall-planted and spring-planted crops such as winter rye and spring wheat. This damage included purple coloration, inhibited lateral root development, and swollen root tips. Flumetralin residue in soils can also damage subsequent tobacco crops (Shelby et al., 1990). When tobacco plants were sprayed with 86 mg a.i. flumetralin per plant, a deliberate over application, subsequent year tobacco plants had significant (at α=0.05) growth reductions. The potential damage to succeeding crops is the motivation to test for flumetralin in this study.

Although few studies were found that observe these two pesticides under different tillage practices, comparisons between other pesticides have been documented. No-till systems were found to decrease atrazine and alachlor in runoff and in leachate samples. Combinations of no-till, conventional tillage and rye residue cover, (0, 750, and 1500 kg ha^{-1}) were studied on Groseclose silt loam soil near Blacksburg, VA (Kenimer et al., 1987). Atrazine was applied at 2.24 kg ha^{-1}, and 2, 4-D at 0.56 kg ha^{-1}. Rainfall was simulated on the research area in a set of three runs. Run 1 was 1 h followed 24 h later by two 30 min runs. Run 2 and run 3 were separated by 30 min. The authors concluded that regardless of tillage practice, runoff volume and sediment losses decreased as rye residue increased. No-tillage with 1500 kg ha^{-1} residue had the largest reduction of runoff volume and sediment losses. Concentrations of both pesticides on sediment and atrazine in runoff water were higher from the no-till treatments. The authors consider that the rougher soil of conventional tillage facilitated runoff water and soil mixing, resulting in more pesticide adsorption to soil particles. Total losses were lower from no-till, however, and total atrazine mass loading was reduced 90% and 2, 4-D was reduced 93% by no-till.

Atrazine and alachlor leaching under tilled and no-till fields were studied on a Alfic Normudult loam soil (Gish, 1995). Fields under continuous corn and rye production were prepared in 1990. Six pairs of suction lysimeters were installed to collect soil water below the active root zone of corn, between 1.5 and 1.8 m. The application rate for atrazine was 1.7 kg a.i. ha^{-1} and for alachlor was 2.8 a.i. ha^{-1}. Alachlor was detected in less than 3% of all lysimeter samples. Atrazine was detected in 41% of all soil water samples. The tilled fields yielded 53 % of solution samples containing atrazine, while only 28% of samples collected under no-till fields contained atrazine. Degradation was the principle factor for atrazine losses on no-till fields. The atrazine metabolite, DEAT, was observed in higher concentrations from this practice.

The authors note a concern that conservation tillage practices may be more susceptible to groundwater pollution if pesticide metabolites are also harmful.

2.4 GLEAMS Modeling

The GLEAMS model is an expansion on the widely used model CREAMS (Knisel, 1980). The purpose of GLEAMS is to evaluate differences between management practices. GLEAMS contains modified hydrology, plant nutrient and pesticide components in order to estimate groundwater loadings and to improve representation of management practices. GLEAMS allows users to examine pesticide transport through soil layers, but still retains the 1 cm effective surface layer. A sensitivity analysis conducted on the pesticide parameter indicates that the pesticide half-life, adsorptivity, and depth of incorporation are sensitive factors. The GLEAMS model was tested using varying sites with specific field data. The results of model testing were that pesticide and bromide runoff and leaching were simulated within the variability of field data.

Cryer and Havens (1999) preformed sensitivity analyses on the GLEAMS model on data from the Mid-Atlantic tobacco area in Virginia, North Carolina and South Carolina. This study proved that the most sensitive parameter in GLEAMS is the SCS Curve Number, which was shown significant for all weather patterns. The following pesticide parameters were also sensitive when the GLEAMS model predicted chlorpyrifos in runoff water: soil porosity, the soil evaporation parameter, pesticide half life in soil, soil organic matter, slope of overland soil profile, monthly mean solar radiation, K_{oc}, and the application rate.

Knisel et al. (1991) observed that GLEAMS overestimated runoff volumes during winter months and underestimated during summer for a sandy Coastal Plain soil. The model also underestimated percolated water volume in the winter and overestimated in the summer months. The authors conclude that fine-tuning the four sensitive hydrology parameters, rooting depth, curve number, porosity and field capacity, improved simulation results only slightly. Updating the mean monthly temperature and radiation data did not significantly improve simulation results. The authors state that where snowmelt and frozen soils are not substantial, calibration is not needed.

Groneau et al. (2001) simulated atrazine losses from a silt loam soil under continuous corn with no-till, ridge tillage and disk tillage treatments with varying herbicide application practices using GLEAMS. The authors report that no-till and ridge tillage yielded 34% and 36% less runoff volume than disk tillage, respectively. Herbicide mass loss was reduced by 17% and 24% for atrazine and 1.3% and 10% for acetacholor for no-till and ridge tillage, respectively. Year-to-year variations in atrazine runoff were large. These values ranged from 0.57 and 1.2% of the amount applied. For recurrence intervals greater than 10 years the practices that showed the greatest reductions in atrazine loss were pre-emergent banded application with ridge tillage and pre-emergent incorporated with disk tillage. The practices that were effective in minimizing average long-term atrazine loss were pre-emergent banded application with ridge tillage, early pre-emergent with no-till, incorporation application with disk tillage, and post-emergent application for all tillage practices.

The GLEAMS model was validated with observed pesticide data for a field planted with corn by Sichani et al. (1991). Percolated water was collected from 20 m spaced, subsurface drains and tested for three pesticides: atrazine, carbofuran and cyanazine. The authors concluded that the GLEAMS simulated pesticide mass values results were lower than the observed pesticide total mass in all but 3 rainfall events. The storm that produced the highest observed peaks of pesticide in percolated water produced only trace amounts of pesticide in percolated water by GLEAMS. The authors believe this is a result of preferential flow traveling to the subsurface drains. Thus more water is being drained and tested than occurs in the natural undrained situation that GLEAMS considers in the simulation. The timing of the peaks corresponded well between observed and simulated values.

A study in Central coast of Virginia evaluated GLEAMS and PRZM for pesticide leaching from no-till corn production. Zacharias et al. (1992) concluded that the models did not predict metolachlor behavior well. Each model simulated atrazine concentration profile in the root zone best. Overall, GLEAMS represented pesticide and bromide concentrations in the soil profile better than PRZM. GLEAMS is superior for modeling pesticide transport under conservation tillage because it models the partitioning of chemicals between residue and soil. The function used in GLEAMS to calculate depth of water extraction led to the under prediction of the soil water in the upper soil layers once transpiration became dominant in the evapotranspiration (ET) process.

Ma et al. (1998) found that GLEAMS and Opus predicted event runoff fairly accurately while PRZM-2 generally over predicted runoff for plots of corn in Tifton loamy sand in Georgia. GLEAMS and Opus under predicted runoff when observed runoff was the greatest. All models use the SCS curve number procedure, however the simulation results were significantly different. All three models are sensitive to the CN and have low sensitivity to measurable parameters.

A study was preformed by Malone et al. (1999) comparing GLEAMS and PRZM-3 predictions of runoff and metribuzin concentrations in soil and runoff waters from compost amended, no-till and conventional tillage treatments on Lowell silt loam soil. Both models under predicted metribuzin in runoff. The under prediction of metribuzin sediment concentration is partially due to over predicting metribuzin transport from the mixing zone (top 1cm) into the sub-mixing zone. Neither model simulated macropore transport, which resulted in the under prediction of subsurface metribuzin. Both models under predicted metribuzin concentration in runoff, sediment, percolation and subsurface soil. Both models over predicted runoff transport.

Smith et al. (1991) compared the root/vadose zone transport model results of PRZM and GLEAMS against experimental pesticide infiltration data from Lakeland sand soils in Georgia. The models were not calibrated or optimized and many parameters were estimated from the users manual. This was done to simulate conditions when a regulator would not have site-specific data. PRZM and GLEAMS were run in a screening mode and the simulated transport closely agreed with each other. The measured and predicted peak concentrations agreed within an order of magnitude and within a factor of 2 or 3.

The literature suggests that GLEAMS simulates runoff volume accurately, although the largest observed events were commonly under predicted. Occurrences and trends of pesticide mass movement with percolated water were estimated accurately. Results were within a reasonable range when input values were default or non site-specific data.

Chapter 3 Methods and Materials

3.1 Site Characteristics and Experimental Design

All data was collected from a burley tobacco field in Smyth County, Virginia. The average annual precipitation in Smyth, County is 1.18 m (46.61 in.) (SCS, 1948). The northern fork of the Holston River flows parallel to the southeastern edge of the tobacco field. Research plots were located on Speedwell sandy loam soil (*fine-loamy, mixed, mesic Fluventic Dystrochrepts, coarse-loamy,*) with moderate permeability. The field has an average 0.8% southeast slope and the research area was oriented southwest to northeast (Figure 3.1). The research plots were oriented parallel to the existing tobacco row direction.

The experiment was a randomized complete block design with three blocks each having three treatments, one treatment per plot. Each plot was prepared with one of the following treatments: conventional tillage (CT), no-till (NT), or strip tillage (ST). Soil was not disturbed before planting through tobacco harvest in the no-till treatment. Strip tillage required disturbing the soil only in the seedbed before transplanting.

Plots 1, 6, and 7 were prepared with CT; plots 2, 5, and 9 were prepared with NT, and plots 3, 4, and 8 were prepared with ST (Figure 3.1). Each plot was 2.1 m wide by 7.0 m long (7 ft by 23 ft). To delineate plots and to facilitate runoff collection, 30-cm (12-in) tall borders were installed after planting to a depth of 15 cm (6 in) around each plot.

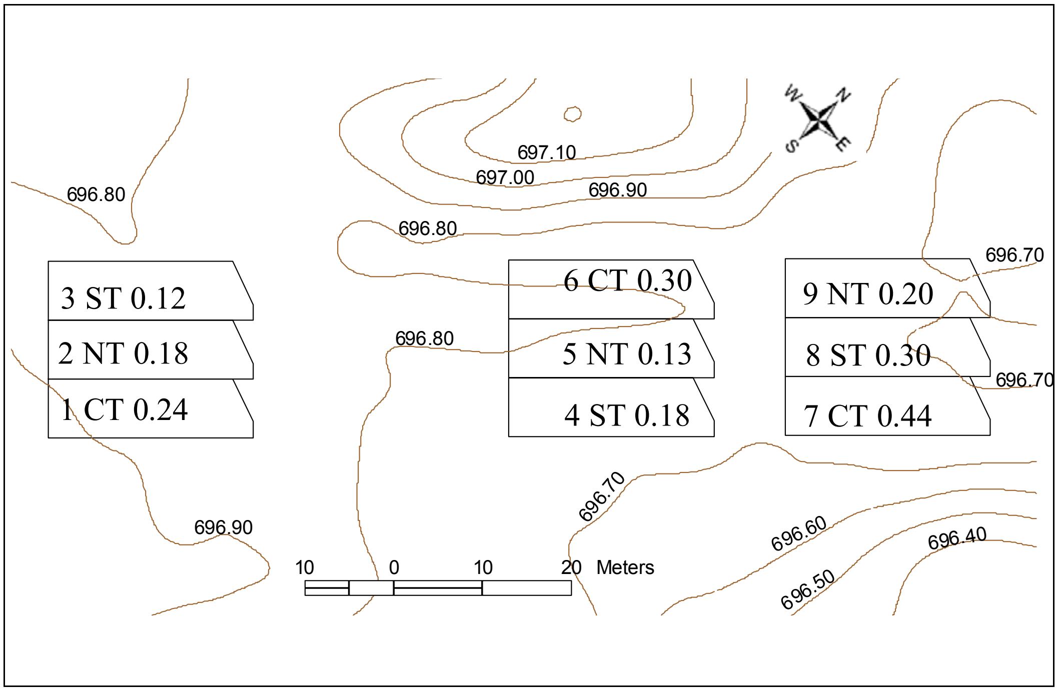


Figure 3.1 The research area with conventional tillage (CT), strip tillage (ST), and no-till (NT) plots with slope in m/m

3.2 Field Experiment

3.2.1 Field Operations

The rye cover crop was plowed under with a moldboard plow on the conventional tillage plots before transplanting. The rye was killed with Roundup (isopropylamine salt of N-(phosphonomethyl)glycine (56)) on the strip tillage and no-till plots. Both operations were preformed on 19 May 2002.

The next day, 20 May 2002, dry fertilizer, with the formula 10-6-18 (N-P-K), was broadcast on all treatments at a rate of 2240 kg ha^{-1} (2000 lbs ac^{-1}). The same day, the insecticide chlorpyrifos (Lorsban) was also surface applied at a rate of 2.242 kg a.i.ha^{-1} (2.0 lb a.i. ac^{-1}). The chlorpyrifos and fertilizer were disked into the conventional till plots after application with a tandem disk harrow operation. No incorporation was performed on the strip tillage and no-till plots.

Two days later, on 22 May 2002, tillage was performed in preparation for tobacco transplanting. Disk tillage was performed on the conventional tillage plots and seedbed preparation was preformed on the strip tillage plots using an in-row chisel operation. The soil in the no-till areas was not disturbed.

Burley tobacco, (*Nicotiana tabacum* L.) variety NC BH 129, was transplanted on 24 May 2002. Rows were centered in the plots and were spaced 1.1 m (42 in) apart.

To control blue mold, the fungicide Acrobat MZ (Morpholide) was broadcast using drop nozzles at a rate of 11.2 kg ha^{-1} (10 lbs ac^{-1}) weekly beginning on 17 June 2002.

In order to optimize leaf area, the growth regulator flumetralin was used to prevent auxiliary buds or sucker growth on the tobacco. Flumetralin was broadcast at a rate of 1.345 kg a.i. ha^{-1} (1.2 lb a.i. ac^{-1}) on 24 July 2002 to all treatments. This same operation was performed a year earlier on 24 July 2001. The tobacco was harvested over a month later on 30 August 2002. The field remained fallow until ryegrass (*Lolium multiflorum* L.) was planted in October 2002 to provide cover during the winter season.

3.2.2 Plot Characterization

The line-transect method described by Shelton et al. (1997) was used to estimate the percentage of rye residue cover. Normally the line-transect method involves recording the number of times a piece of residue touches one side of a 100-ft (30.48-m) measuring tape. Touches or counts are assessed at one-foot (0.305-m) intervals. The number of counts equals the percent of residue cover present on the land surface. Normally three or more random locations in a field are assessed and average of these three assessments reported as percent cover.

Figure 3.2 Line-transect method as used in the plots

For this study the line transect method was modified to accommodate the relatively small plot size (Figure 3.2). For each plot, a measuring tape was extended diagonally from the southeastern corner of each plot to the middle of its opposite side (Figure 3.3, line 1), a distance of approximately 3.8 m (12.5 ft). Along the 3.8 meters (12.5 ft) of measuring tape, 25 intervals at 15.2 cm (6 in), were assessed for residue. If a piece of residue touched one side of the tape as the specified distance, a count was recorded. The measuring tape was then pivoted, extended from the midpoint of the plot border to the corner opposite the pivot point (Figure 3.3, line 2). This zigzag pattern was repeated from the northwestern corner (Figure 3.3, line 3 and 4).

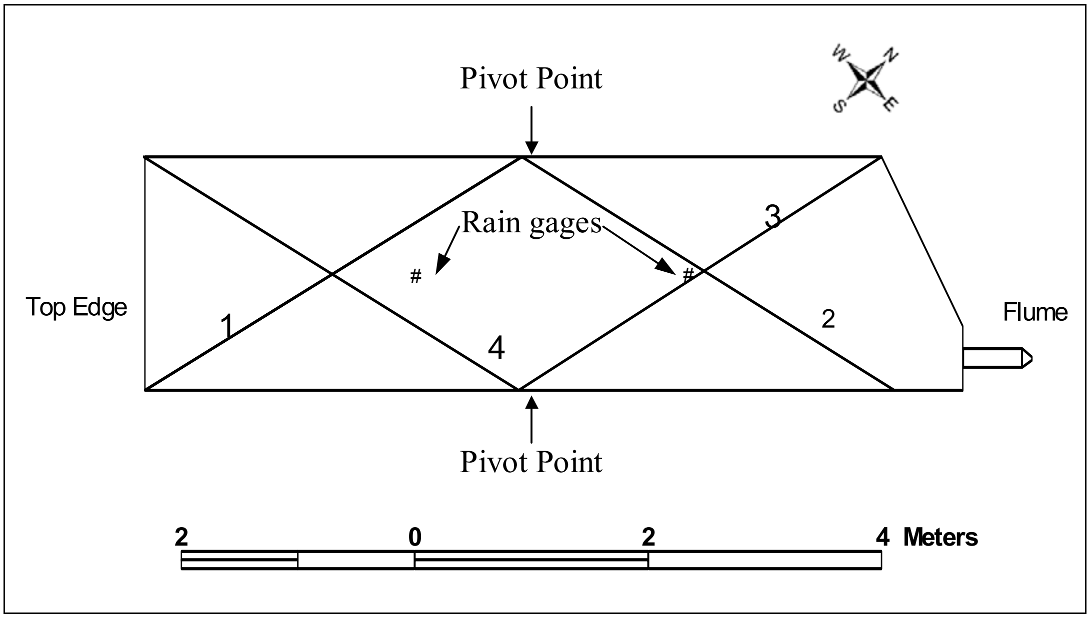


Figure 3.3 A representation of the modified line-transect method

The modified procedure had a maximum of 100 counts. The percent residue cover per plot was calculated as the sum of all counts on the four diagonals. After initial measurements were recorded, rye collected from an adjacent field was added to the strip tillage and no-till plots, to increase the difference in residue cover between treatments (Figure 3.4). The increase in the residue cover on the strip tillage and no-till plots was done so the treatments would accurately represent established conservation tillage practices. Strip tillage commonly has 60 to 65 percent residue cover on average; no-till has 80 to 85 percent (CTIC, 2003). The line-transect method was preformed one additional time to measure the final percent residue cover. The results of the modified line transect method are shown in (Table 3.1). After additional residue was added, the average rye residue cover for the conventional tillage treatment was 5 percent, 59 percent for the strip tillage treatment, and 82 percent for the no-till treatment.

Figure 3.4 Plots 1 (no-till), 2 (conventional tillage) and 3 (strip tillage)

Table 3.1 Residue cover results

Treatment	Residue Cover
	%
CT	5
ST	59
NT	82

Three representative soil samples were collected for nutrient analysis (one from each block). Four cores, 1.9 cm (0.75 in.) in diameter, were taken along the center of each plot to a depth of 30.5 cm (12 in.). The middle 15.2 cm (6 in.) of these cores were combined to make one sample per plot. Samples from plots 2, 5 and 8 were tested for nutrients. Four soil samples were collected from random places around the research area to determine the antecedent moisture content of the soil before each series of rainfall simulations.

3.2.3 Rainfall Simulation and Runoff Collection

The rainfall simulator set-up (Dillaha et al., 1988) used in this study consisted of four rows of 7.6-cm (3-in.) diameter laterals spaced 6.1 m (20.0 ft) apart (Figure 3.5). Simulator laterals were supported with iron stakes 0.15 m (0.5 ft) above the ground. The risers were 2.4 m (7.87 ft) tall and were aligned in a triangular pattern with a spacing to provide adequate rainfall uniformity. Each riser was outfitted with flow control valves and Rainjet 78C nozzles.

Figure 3.5 Rainfall simulator set-up

Water for the rainfall simulations was pumped from the northern fork of the Holston River using a Deutz 75 kW (100 Hp) pumping unit. The pressure was 193 kN m^{-2} (28 psi) at the test riser at the end of the lateral nearest the river. The simulator applied artificial rain at a maximum of 50.8 mm h^{-1} (2 in h^{-1}). Source water samples were collected at the end of each simulation. These samples were analyzed for the same constituents using the same procedures as those employed for other samples collected. These raw water samples were collected and tested to compare to runoff and percolated water samples.

Two rainfall simulation series were conducted with three simulation runs per series. Series 1 occurred on 13 June and 14 June 2002; series 2 occurred on 2 July and 3 July 2002. The rainfall simulation series was manipulated during the experiment due to a lightening storm with that disrupted the first June simulation run. June Run1 was stopped for safety reasons. No appreciable rainfall was measured from this storm. The duration of Run1 was decreased from 60 min to 50 minutes. In order to obtain the same quantity of total precipitation applied to the plots, the duration of Run2 was increased by 10 min. This simulation pattern was repeated for the July series. Each series included three runs: Run1, 50 min; Run2, 40 min; and Run3, 30 min. Runs 2 and 3 were conducted 24 h after the first run and were separated by 1 h. The purpose of this sequence was to simulate rainfall when the soil was dry (Run 1), wet (Run 2) and very wet (Run 3). The average intensity for the two series was 1.76 in h^{-1} (44.7 cm h^{-1}), 1.68 in h^{-1} (42.7 cm h^{-1}), and 1.69 in h^{-1} (42.9 cm h^{-1}) for Run1, Run2 and Run3, respectively. Two rain gages were placed in each plot to measure the amount of rainfall applied to each plot and to determine the uniformity of the simulated rainfall. Rain gauges were located between the rows of tobacco at 2.33 m (7.64 ft) and 4.67 m (15.3 ft) from the upslope edge of each plot (Figure 3.3). After runoff ended, the precipitation depth from each plot was recorded at specific intervals.

The northeast plot borders (Figure 3.1) were angled to the northeastern corner where 6-inch H-flumes were installed. Joints in the plot borders, and between the flume and flume approach-boards were sealed with a silicone sealant to isolate the plots hydraulically and to ensure that all runoff from the plots was channeled through the flumes. Ditches were dug at the outlet of each flume to facilitate runoff drainage and to provide adequate space for sample collection.

Runoff volume measurements were collected from the flume outlet and recorded for each plot. A 4-L bucket, calibrated every 250 mL, was used to measure the volume of runoff. The bucket was placed under the flume outlet for 20 s and the volume was recorded.

As per proper collection techniques for the pesticides present, one-liter bottles were prepared with an acetone rinse to collect water quality samples.

A pattern for collecting flow measurements and water quality samples was established prior to the field study and followed throughout. The sampling pattern required alternating between collecting water quality samples and recording volume measurements. Water quality sample collection was slated for 3, 9, 15, 21, 27 minutes and so on from the start of the simulation. Runoff volume measurements were slated for 6, 12, 18, 24, 30 minutes and so on from the start of the simulation. The time runoff began was recorded for each plot. An initial water quality sample was collected one minute after runoff began to collect the first flush of contaminants from the plots. After this sample was collected, the sample collection and volume measurements continued at the next appropriate, prescribed time. A volume (flow rate measurement) or water quality sample was taken every 3 minutes throughout the simulation.

In the July rainfall series, the initial water quality sample collection one minute after runoff began was eliminated. Data was lost when this collection occurred at a time slated for a volume measurement.

Porous-cup lysimeters were used to collect vadose zone water samples at the effective rooting depth of tobacco, 45.7 cm (18 in). These water samples were used to determine solution-phase concentrations of nutrients and agricultural chemicals below the root zone. The lysimeters were constructed with 0.6 m (2 ft) of PVC pipe with a 50.8-mm (2-in.) inner diameter. A model 0653, porous ceramic, round bottom, neck top cup with an air entry value of 0.5 bars at high flow was attached to the bottom of the PVC pipe with epoxy (Soil Moisture Co., 2002). The cups had a 4.8-cm outer diameter and 6.05-cm length. Two tubes extended through a rubber stopper and into the pipe. The tube that extended the entire length of pipe and cup was used to collect samples and the shorter tube was used to create a vacuum. Both tubes extending from the stopper were bent and capped to prevent contamination of the lysimeter samples. Due to numerous large cobbles in the soil, lysimeter installation depth varied from 0.38 m to 0.46 m (15 to 18 in.). Holes were dug using a Riverside Bucket Auger model 290047. The soil from the deepest horizon was combined with water to make slurry. The slurry was poured into the auger hole to ensure good lysimeter to soil contact. Each soil horizon was packed tightly around the lysimeter to eliminate artificial soil pores. Three lysimeters were installed in each plot between the rows of tobacco at distances of 1.75 m (5.75 ft), 3.5 m (11.5 ft), and 5.26 m (17.25 ft) from the southern (upslope) edge.

After Run 3 of each simulation series, a vacuum ranging from 400 to 450 KPa (40 to 45 cbars) was pulled on each lysimeter. Soil water samples were collected 72 h after Series 1 was completed. In an effort to obtain more sample volume, the time between Series 2 completion and lysimeter sample collection was reduced to 24 h.

3.3 Sample Analysis

Runoff samples were analyzed for two pesticides, chlorpyrifos (chlorpyrifos) and Prime Plus (flumetralin). One-liter, flow-weighted runoff composites were created for each plot for each rainfall simulation run to test for the pesticides. To create the flow-weighted composite samples, individual flow rate (mL s^{-1}) data points on the runoff hydrograph were calculated by dividing each volume measurement taken during the simulation run by the 20 s collection duration. The flow rate values were graphed verses time to create a hydrograph for each plot. The hydrographs were numerically integrated to determine the total runoff volume from each plot. Sample intervals were recorded as the difference between any two consecutive sample collection times (a typical sample interval was six minutes). The sample period (the length of time during the hydrograph attributed to any given flow rate data point) was calculated as half of the difference between the previous sample interval and the current sample interval plus half the difference between the next sample interval and the current sample interval. The fractional runoff volume attributed to any given sample period was calculated as the corresponding sample period flow rate multiplied by the sample period divided by the total runoff volume collected during a simulation run. This process was completed for each volume recorded in the field and resulted in a 1-L composite sample.

To determine the concentration of chlorpyrifos and flumetralin in the water quality runoff and lysimeter samples a liquid-liquid extraction method was used (EPA-600/8-80-038). Methyl chloride was used to extract the pesticide compounds from the water sample. The methyl chloride was evaporated off and hexane is added before the sample was placed in a gas chromatography machine, which detected the amount of pesticide in the sample. The specifications of the HP6890 μECD machine are shown in Appendix B. The detection limit was defined as 0.3 μg L^{-1} for both pesticides. The lysimeter samples were combined based on tillage practice for pesticide testing. Each series had three lysimeter samples tested for pesticides, one from the conventional tillage plots, one from the strip tillage plots, and one from the no-till plots.

Samples collected during the rainfall simulation were analyzed for nitrate (NO_3^-), ammonia (NH_3), total Kjeldahl nitrogen (TKN), orthophosphate (PO_4^{3-}), total phosphorus (TP), and total suspended solids (TSS). The amount of TSS was determined by the difference in weight of clean, dry filter paper and the same filter paper with solids present (EPA 160.2). The tests for NO_3^- (EPA 353.1), PO_4^{3-} (EPA 365.1), NH_3 (EPA 350.1), TKN (EPA 351.2), and TP (EPA 365.1) were conducted using an Odyssey DR/2500 Spectrophotometer and corresponding procedures. Total nitrogen (TN) values were calculated by adding NO_3^- and TKN values. Thirty mL of each lysimeter sample was tested for nutrients.

3.4 Flow Rate Analysis

Hydrographs were generated from all plots for all rainfall simulations. The hydrographs from June series Run 1 had incomplete falling limbs due to missing volume measurements of the truncated run. To compensate for the missing data, the time from the flow rate peak to the end of runoff for Run 2 and Run 3 were averaged. This average was used as an estimate of the time required for the falling limb of Run 1 to reach zero mL s^{-1}. The hydrographs of the conventional tillage (CT) plots (1, 6, and 7) for the June simulation series Run 1 are shown in Figure 3.6. The southern most block (plots 1, 2, and 3) had a slightly steeper slope, which accounts for the greater peak flow rate and total runoff volume from Plots 1, 2 and 3. The general trend for each tillage practice showed that CT generated the greatest volume of runoff and NT generated the least runoff volume. All June and July simulation series hydrographs are shown in Appendix A.

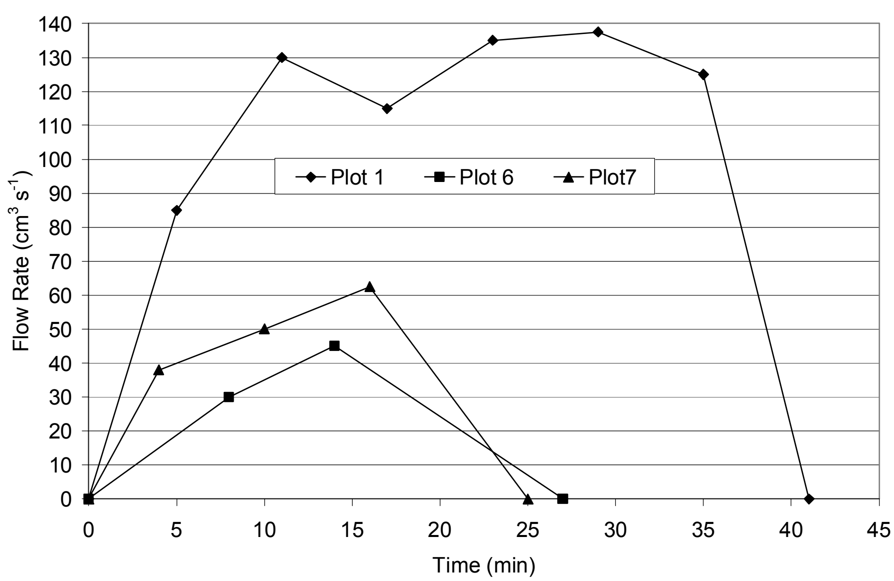


Figure 3.6 Hydrographs for the conventional tillage treatments for June simulation series Run1

3.5 Data Analysis and Statistics

The water quality samples collected during each run were analyzed for nutrient, sediment, and pesticide concentrations. A volume-weighted average concentration was calculated for every plot. Total mass loadings of pollutants were calculated because, unlike concentration values that change when two bodies of water mix, total mass values are constant. Mass values were determined by multiplying the concentration of the constituent by the corresponding volume of runoff. The total mass of a particular constituent lost in either surface runoff or leachate for a given plot was determined by adding individual mass values for a single simulation run.

A water balance was performed to determine the volume of water infiltrated through the soil profile. The soil storage capacity was calculated by multiplying the difference between the soil field capacity and the antecedent moisture content by the plot area and by the rooting depth, 45.7 cm (18 in.). The volume of water that percolated past the active root zone was determined by subtracting the runoff volume and storage capacity from the total precipitation. The average concentration of each constituent was multiplied by the total percolated volume to calculate the mass of constituent lost below the active root zone.

The experiment was a randomized complete block design. The null hypothesis tested whether all treatments had equal loss of nutrient, sediment and pesticides in runoff and below the active root zone (H_o: CT = ST = NT). A 95% confidence interval was used to test for statistical significance ($\alpha = 0.05$). Literature suggests that conventional tillage will produce higher averages of pollutants in runoff (Stein et al., 1986). Due to this preliminary notion, two specific contrasts were used to examine the data. The first contrast tested whether constituent mass or concentration values in either the runoff or deep percolation samples from CT treatments were statistically different from the average constituent mass or concentration values from ST and NT treatments (H_{o1}: CT – 0.5(ST + NT) = 0). The second contrast tested specifically whether constituent mass or concentration values from the ST treatment were statistically different from constituent mass or concentration values from the NT treatment (H_{o2}: ST = NT). These contrasts were examined only if the null hypothesis (H_o) of the treatments proved statistically significant. The statistical procedure used was general linear model. Lastly, a protected

Fisher's least significant difference (LSD) test was used to show grouping within the data. The LSD was examined only if the null hypothesis (H_o) of the treatments proved statistically significant. All statistics were analyzed with Statistical Analysis Software, SAS (SAS, 1995). All statistical code used for analysis is shown in Appendix C.

3.6 CLIGEN Weather Generator

The model CLIGEN was used to generate 50 years of daily precipitation and daily average temperature for input into the GLEAMS model. A 50-year data set for Southwestern Virginia was generated by the climate generator CLIGEN (Richardson and Nicks, 1990). The weather station in the CLIGEN 4.2 database closest to Atkins, Virginia was Burkes Garden, Virginia in Tazewell County. This station is approximately 26 km (16 miles) northeast of Atkins. The 50 years of daily rainfall and daily average temperature data was used by the GLEAMS model to simulate the long-term effects of tillage practices on a burley tobacco field.

3.7 GLEAMS Modeling

The GLEAMS model was used to assess the long-term water quality benefits of conventional and conservation tillage practices on a common tobacco production system in Southwest Virginia. Simulated edge-of-field losses were compared on a relative basis over a 50-year simulation period for the same three tillage treatments evaluated in the field portion of this study. The tobacco field used in the GLEAMS simulation was a 2.93 ha (7.25 ac) burley tobacco field with an average 0.8 percent slope. The estimated mean sea level was 697.9 m (2290 ft) and latitude was 36.8792 degrees North. The characteristics of the simulation field corresponded to the Southwest Virginia climate, field conditions and soil characteristics. Average monthly values for maximum temperature, minimum temperature, dew point, wind speed, and radiation used by the model were obtained from the Wytheville South weather station approximately 24.1 km (15 miles) from the field research site.

Information gathered from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) and the Crop and Soil Environmental Sciences department at Virginia Tech (J. Freyman, personal communication, 30 September 2003; Dr. J. Baker, personal communication, 29 September and 2 October 2003) was used to specify soil properties as input to the hydrology and erosion components of GLEAMS. The properties of the soil at the field experiment site were used for the GLEAMS simulation. The soil was a Speedwell sandy loam soil profile consists of an Ap horizon (0-25.4 cm), an A horizon (25.4-45.7 cm), a Bw horizon (45.7-106.7 cm), and a C horizon (106.7-182.9 cm or bedrock). The properties of the Ap and A horizons are very similar and therefore, soil parameter inputs were estimated for the A horizon as a whole. The root zone of tobacco (0-45.7 cm) encompasses the entire A horizon of the Speedwell soil. Soil organic matter was 2.5 percent in the A horizon of the CT practice and 2.7 percent for the strip tillage and no-till practices. The typical rooting depth for mature tobacco, 45.7 cm (18 inches), was used for all tillage practices (Burley Tobacco Production Guide, 2002). It was assumed that below 45.72 cm (18 in) percolated water and any dissolved nutrients and pesticides would be lost to deep percolation and may enter the groundwater supply.

The GLEAMS hydrology component simulates runoff using daily rainfall and a modified SCS curve number method. Daily rainfall values were generated from the CLIGEN weather generator. The Priestly-Taylor method was chosen to calculate evapotranspiration (ET) due to its effectiveness in temperate regions. According to the GLEAMS 3.0 manual (Knisel, 1999) the curve number is a sensitive parameter in estimation of runoff volume. Curve numbers were estimated using the GLEAMS 3.0 manual guidelines (Knisel, 1999). The curve number for conventional tillage was estimated from the high end of the range given for a straight row crop on a hydrologic soil group (HSG) B with good hydrologic condition. Only one range of values were given for conservation tillage on a straight row crop with the HSG B with a good hydrologic condition. The strip tillage curve number was therefore estimated from the high end of this range and the no-till curve number was estimated from the middle of the same range. Rooting depth, curve number, and the values used for the other sensitive parameters in GLEAMS are show in Table 3.2.

Table 3.2 Sensitive parameter values used in long-term GLEAMS simulation

	GLEAMS Parameter			
Tillage Practice	Curve Number	Rooting Depth (inch)	Porosity ($in^3\ in^{-3}$)	Field Capacity ($in\ in^{-1}$)
CT	82	18	0.51	0.20
ST	79	18	0.51	0.20
NT	76	18	0.51	0.20

The tobacco field was designated as a majority of overland flow and not channel or gully flow due to the slight slope. Crop cover, management practice, and Manning's roughness factors are entered into the erosion component to simulate soil disturbance throughout the crop rotation. These factors are used in the Universal Soil Loss Equation and are updated during the year. The soil erodibility factor (K) was selected from Speedwell sandy loam soil information and the differences in the percent of organic matter. The soil erodibility factor for conventional tillage was 0.2275 and the conservation tillage practice K value was 0.2225.

The pesticide component was parameterized to simulate the Smyth County tobacco field conditions assuming the same field operations observed during 2002. The pesticide-specific GLEAMS default values for the soil half-life and organic carbon partition coefficient (K_{oc}) were used (Knisel, 1999). The soil half-life and K_{oc} values were 15.0 days and 6070 for chlorpyrifos and 20.0 days and 10,000 for flumetralin, respectively. The relatively high K_{oc} values indicate that both pesticides are strongly adsorbed to sediment particles and less likely to be dissolved in runoff water. The water solubility was 1.39 mg L^{-1} for chlorpyrifos and 0.1 mg L^{-1} for flumetralin. The insecticide application was partitioned to the soil surface and crop canopy cover. The majority of the flumetralin was applied to the tops of the tobacco plants, with a small amount dipping to the soil surface. This was modeled by assuming a 0.8 fraction of the herbicide was applied to the foliage and 0.1 was applied to the soil surface. The remaining 10 percent was assumed to be lost to drift. The flumetralin residue fraction on the soil surface when simulation began was assumed to be 0.4. All GLEAMS input parameter files are shown in Appendix D.

The annual totals in the GLEAMS output were analyzed using the plotting position recurrence interval, or return period, procedure. The recurrence interval is the inverse of the probability that an observed event in a given year is equal to or greater than a given event. In this study the annual totals of runoff volume, nutrient, sediment and pesticide mass loss were ranked in descending order, 1 through 50, for each tillage practice. The plotting position was calculated as the rank divided by the number of years in the study, 50, plus 1. The recurrence interval in years was the inverse of the plotting position.

Chapter 4 Results and Discussion

4.1 Field Experiment

The primary objective of the field experiment portion of this study was to measure sediment, nutrient, and pesticide edge-of-field losses from a burley tobacco production system. To accomplish this, water quality and volume samples were taken from tobacco plots during six rainfall simulations. Soil water samples were collected from lysimeters after both simulation series. Three tillage treatments (conventional-till, strip tillage and no-till) were investigated using a randomized complete-block experimental design. Runoff samples were tested for the following constituents: nitrate (NO_3^-), ammonia (NH_3), total Kjeldahl nitrogen (TKN), orthophosphate (PO_4^{3-}), total phosphorus (TP), total suspended solids (TSS), and two pesticides, chlorpyrifos (Lorsban) and flumetralin (Prime Plus). Total nitrogen (TN) values were calculated by adding NO_3^- and TKN values. Lysimeter samples were tested for all these constituents except TSS.

4.1.1 Simulated Rainfall

Christensen's uniformity coefficient was calculated for each run during both simulation series. A uniformity of 80% is considered acceptable (Christensen, 1949). The uniformity coefficient values of simulated rainfall ranged from 90.5 to 94.5 percent. The recurrence intervals were derived from TP-40 equations and HYDRO-35 precipitation charts and are shown in Table 4.1 (Weiss, 1962; Shanholz and Lillard, 1974).

Table 4.1. Rainfall simulator data

Event Date	Rainfall Simulation	Average Rainfall Depth (in)	Average Rainfall Depth (mm)	Rainfall Intensity (in h^{-1})	Rainfall Intensity (mm h^{-1})	Recurrence Interval/Duration*	Recurrence Interval/Duration†	Uniformity Coefficient‡ (%)
June 13	Run1	1.43	36.2	1.71	43.5	2yr 50min	2yr 50min	93
June 14	Run2	1.06	27.0	1.59	40.4	1yr 40min	2yr 40min	94
June 14	Run3	0.78	19.9	1.57	39.9	1yr 30min	2yr 30min	91
July 2	Run1	1.51	38.4	1.82	46.1	2yr 50min	5yr 50min	91
July 3	Run2	1.17	29.8	1.76	44.7	2yr 40min	2yr 40min	94
July 3	Run3	0.91	23.1	1.82	46.2	1yr 30min	2yr 30min	95

* Determined by method outlined in TP-40 report by Weiss, 1962
† Determined by method outlined in Shanholz and Lillard 1974
‡ Determined from equation presented in Christensen, 1949

4.1.2 Source Water Chemical Analysis

The rainfall simulation source water drawn from the Holston River was tested for NO_3^-, NH_3, TKN, PO_4^{3-}, TP, TSS and the two pesticides, chlorpyrifos and flumetralin (Table 4.2). The source water constituent values were not subtracted from constituent values detected in the runoff samples to ensure positive constituent concentration and mass values, but are reported for comparison. The differences in concentration values between the June runs were minor so only one source water sample was collected and tested from the July series.

Table 4.2. Constituent concentrations in source water

		Raw Water Concentrations								
Date	Rainfall Simulation	NO_3^- (mg L^{-1})	NH_3 (mg L^{-1})	TKN (mg L^{-1})	TN (mg L^{-1})	PO_4^{3-} (mg L^{-1})	TP (mg L^{-1})	TSS (mg L^{-1})	Chlorpyrifos (μg L^{-1})	Flumetralin (μg L^{-1})
13 June	Run 1	0.80	0	0.22	1.02	0.22	0.14	219	--*	--*
14 June	Run 2	0.50	0	0.44	0.94	0.17	0.09	122	--*	--*
14 June	Run 3	0.20	0.20	0.46	0.66	0.04	0.10	247	--†	--†
3 July	Run 3	0.90	0.33	0.49	1.39	0.19	0.16	36	--†	--†
	Average	0.60	0.13	0.40	1.00	0.16	0.12	155.95	--	--

* Only one source water sample from each series was tested for pesticides
† Pesticide not detected or was below detection limit, 0.3 μg L^{-1}

4.1.3 Statistical Analysis of Runoff Data

The treatment average runoff volume, constituent concentrations in the runoff and lysimeter samples, and the surface runoff mass loss values along with the statistical analysis results are discussed in the sections 4.1.1.1 through 4.1.1.8. With respect to the statistical analysis, an $\alpha = 0.05$ is considered to be statistically significant. Where appropriate, treatment means were grouped using Fisher's least significant difference (LSD) multiple comparison test. In Table 4.3 through Table 4.6 and Table 4.9 through Table 4.11, letters following constituent means are used to illustrate the grouping of the means. The coefficient of variation, an indication of the variability or the spread of the data are also presented.

4.1.3.1 June Simulation Series Results

The results of the runoff volume, nutrient, and sediment concentration analysis for the June simulation series are shown in Table 4.3. The runoff volume results are shown in Table 4.3, and are discussed in the total mass results section.

Table 4.3. Runoff volume and nutrient and sediment concentrations for the June simulation series

			June						
			Concentration in Runoff						
Rainfall Simulation	Tillage Treatments	**Volume** (L)	**NO_3^-** ($mg\ L^{-1}$)	**NH_3** ($mg\ L^{-1}$)	**TKN** ($mg\ L^{-1}$)	**TN** ($mg\ L^{-1}$)	**PO_4^{3-}** ($mg\ L^{-1}$)	**TP** ($mg\ L^{-1}$)	**TSS** ($mg\ L^{-1}$)
Run 1- Dry	**CT**	135	1.49	0.76	9.83a	11.3	0.48	4.54	2188a
		0.93†	0.08	0.41	0.25	0.22	0.45	0.26	0.21
	ST	70.7	1.06	0.28	6.13b	7.19	0.74	2.95	1372b
		0.91	0.42	0.52	0.19	0.03	0.30	0.36	0.54
	NT	95.3	2.22	0.58	7.11b	9.33	1.09	2.95	1156b
		0.95	0.43	0.38	0.38	0.04	0.37	0.40	0.42
	p value*	0.6952	0.2147	0.1024	0.0424	0.1051	0.1202	0.0547	0.0299
	contrast 1*	--	--	--	0.0192	--	--	--	0.0128
	contrast 2*	--	--	--	0.3699	--	--	--	0.4346
	LSD values‡	--	--	--	2.71	--	--	--	691
Run 2 - Wet	**CT**	235	1.02	0.51	7.15	8.17	0.38b	3.09	1743
		0.22	0.30	0.60	0.59	0.52	0.44	0.47	0.40
	ST	175	0.64	0.31	5.12	5.76	0.62ab	1.87	1242
		0.21	0.58	0.49	0.10	0.14	0.15	0.38	0.25
	NT	134	1.11	0.69	5.66	6.77	0.79a	1.64	855
		0.38	0.32	0.28	0.15	0.07	0.13	0.06	0.04
	p value*	0.0911	0.2278	0.2966	0.6458	0.5389	0.0419	0.1568	0.153
	contrast 1*	--	--	--	--	--	0.0232	--	--
	contrast 2*	--	--	--	--	--	0.1742	--	--
	LSD values‡	--	--	--	--	--	0.288	--	--
Run 3 - Very Wet	**CT**	204a	0.8	0.28	6.29	7.10	0.41	2.54a	1515
		0.13	0.05	0.30	0.37	0.33	0.23	0.13	0.29
	ST	160ab	1.05	0.28	4.65	5.70	0.62	1.50b	940
		0.17	0.63	0.54	0.58	0.59	0.29	0.42	0.30
	NT	114b	0.65	0.22	4.40	5.05	0.74	1.67b	802
		0.43	0.23	0.24	0.21	0.17	0.17	0.38	0.18
	p value*	0.0213	0.5609	0.6297	0.4025	0.4864	0.1019	0.014	0.0551
	contrast 1*	0.0144	--	--	--	--	--	0.0057	--
	contrast 2*	0.0662	--	--	--	--	--	0.4591	--
	LSD values‡	51.8	--	--	--	--	--	0.568	--

* Significant at the 0.05 level.
† Coefficient of variation
‡ Fisher's least significant difference values

June Run1: Concentration

Examining June Run1, the concentration data indicate there were statistically significant differences between the tillage treatments for TKN and TSS, p-values of 0.424 and 0.299, respectively (Table 4.3). The Run1 Contrast1 p-values for TKN and TSS concentrations indicate that the CT treatment yielded significantly greater TKN and TSS concentrations than the average of the ST and NT treatments. The average TKN concentration from the ST and NT treatments was 6.62 mg L^{-1}, 33 percent lower than the TKN concentration from CT, 9.83 mg L^{-1}. The average TSS concentration from the ST and NT treatments, 1264 mg L^{-1}, was 42 percent lower than the TSS concentration from CT, 2188 mg L^{-1}. The Run1 Contrast 2 was not statistically significant for TKN or TSS concentration indicating that there was no significant difference between the two conservation tillage treatments, ST and NT. The greater average TSS concentration from the CT treatments may be due to the increased tillage operations. The CT plots were prepared with a moldboard plow to kill the rye cover crop. This implement cuts and turns the soil to a depth of 15.2 cm. The fertilizer and chlorpyrifos pesticide were both disked into the soil. These intensive practices loosened the soil on the surface and without residue cover to reduce erosive forces, sediment was easily carried off the plots in runoff water. The greater TKN concentration from the CT treatment may correspond to the TSS losses. Total Kjeldahl nitrogen is comprised of ammonia and organic nitrogen. Organic nitrogen and ammonia adsorb to the soil surface and can be transported with total suspended solids (TSS) during a highly erosive storm. The LSD results from June Run1 for TKN and TSS concentrations show that as expected, the ST and NT treatment means were grouped together.

The trend evident during June Run1 showed that the average NO_3^- concentration was reduced 29 and -48 percent by ST and NT, respectively, compared to CT. Negative percent reductions indicate that the conservation tillage practice yielded a greater average constituent concentration than the CT treatment. The ST and NT treatments reduced the NH_3 concentration by 24 and 63 percent, respectively, compared to the CT treatment. The TN value includes NO_3^-, NH_3, and organic nitrogen. The ST and NT treatments reduced the average TN concentration by 37 and 18 percent, respectively, compared to the CT treatment. The average TP concentration was 35 percent lower from both the ST and NT treatment than the CT treatment. The trend for PO_4^{3-} concentration was much different during June Run1. The ST and NT treatments reduced the average PO_4^{3-} concentration by -56 and -129 percent compared to the CT treatment. Both conservation tillage practices yielded higher average PO_4^{3-} concentrations than CT.

June Run2: Concentration

The same trend for PO_4^{3-} was observed for June Run1 and Run2 (Table 4.3). The concentration data from June Run2 indicates there was a statistically significant difference between the tillage treatments for PO_4^{3-} with a p-value of 0.0419. The June Run2 Contrast1 p-value for PO_4^{3-} concentration indicates that the CT treatment yielded a significantly lower PO_4^{3-} concentration than the average of the ST and NT treatments. The average PO_4^{3-} concentration from the ST and NT treatments was 0.71 mg L^{-1}, which is 46 percent greater than the PO_4^{3-} concentration from CT, 0.38 mg L^{-1}. The Run1 Contrast 2 was not found statistically significant indicating that there in no significant difference between the two conservation tillage treatments, ST and NT, regarding the PO_4^{3-} concentration. The LSD results from June Run2 for PO_4^{3-} concentration show that the ST and NT treatment means were grouped together.

The same trend was shown for June Run1 and Run2 for NO_3^- concentration. Compared to CT, the ST and NT treatments reduced NO_3^- concentration by 37 and -9 percent, respectively. The negative percent reduction shows that NT yielded a higher average NO_3^- concentration than CT. The trends developed during June Run2 show that the trend for NH_3 concentration was different than June Run1; the NT treatment yielded a greater average NH_3 concentration than the CT and ST treatment. The ST and NT treatments reduced average TKN concentration by 28 and 21 percent, respectively, compared to the CT treatment. The ST and NT treatments reduced the average TN concentration by 29 and 17 percent, respectively, compared to the CT treatment. Regarding the TP concentration, the ST and NT treatments reduced the average concentration by 40 and 47 percent, respectively, compared to the CT treatment. Compared to the CT treatment, ST reduced the average TSS concentration by 29 percent and NT treatment reduced TSS concentration by 51 percent.

June Run3: Concentration

The trend for TP concentration was different from June Run3 (Table 4.3) than Run1 and Run2; the CT treatment yielded the greatest TP concentration, however, the NT treatment yielded more than the ST treatment. The results from the June Run3 concentration data indicate there were statistically significant differences between the tillage treatments for TP concentration, p-values of 0.014. The Run3 Contrast1 p-values for TP concentration indicate that the CT treatment yielded a significantly greater TP concentration than the average of the ST and NT treatments. The average TP concentration from the ST and NT treatments was 1.58 mg L^{-1}, 38 percent lower than the TP concentration from CT, 2.54 mg L^{-1}. The Run3 Contrast2 was not found statistically significant for TP concentration indicating that there was no significant difference between the two conservation tillage treatments, ST and NT. With respect to TP, the LSD grouping from June Run3 shows that the NT and ST treatment means are grouped together and that the CT treatment is in a group alone.

The trend for NO_3^- concentration from June Run3 was different than June Run1 and Run2. For June Run3, the ST treatment yielded the greatest NO_3^- concentration than the CT and NT treatment. The NH_3^- concentration trend from June Run3 was also different than the trends from Run1 and Run2. The CT and ST treatment yielded equal average NH_3^- concentrations and the NT treatment reduced the concentration by 20 percent. The ST and NT treatments reduced the average TN concentration by 20 and 29 percent, respectively, compared to the CT treatment. The June Run3 trend for TKN was different than the trends developed during June Run1 and Run2. June Run3 results showed that ST and NT reduced the TKN concentration by 26 and 30 percent, respectively, compared to the CT treatment. The CT treatment yielded the highest average TSS concentration; ST and NT reduced the TSS concentration by 38 and 47 percent compared to the CT treatment. The ST and NT treatments yielded 51 and 81 percent reductions of PO_4^{3-} concentration, respectively, compared to CT. The negative reductions show that the conservation tillage practice yielded higher average PO_4^{3-} concentrations than the CT treatment.

June Overall: Concentration

The same TSS concentration trend was observed throughout the June runs. The conventional tillage treatment yielded a higher average TSS concentration than the strip tillage treatment, which yielded a higher average concentration than the no-till treatment.

A converse trend for PO_4^{3-} concentration was also observed throughout the June runs. The no-till treatment yielded a higher average PO_4^{3-} concentration than the ST treatment, which yielded a higher average concentration than the CT treatment. The concentration results of the other constituents did not show consistent trends throughout the June runs.

Although the results were not statistically significant, the NO_3^- concentration from the NT treatment was greater than the CT treatment from June Run1 and Run2; the NO_3^- concentration from the ST treatment was greater than the CT treatment from Run3. The nitrogen and phosphorous results are consistent with data reported by Miller et al. (1994), who concluded that there is potential for dissolved inorganic phosphorous and nitrogen leaching from cover crops. They reported that annual ryegrass (*Lolium multiflorum* L.) leached about 30% of the biomass phosphorous. The results of a study by Barisas et al (1978) showed that increased residue cover did not effectively reduce the losses of water-soluble nutrients due to leaching from residue and reduced fertilizer incorporation. The leaching of phosphorous and nitrogen from the residue cover may explain the high concentrations of soluble phosphorous and nitrogen from the NT and ST treatments.

June Total Mass

The concentration, or mass divided by volume, of a constituent in runoff changes when this runoff enters a body of water. Total mass values are static and do not change when runoff enters lakes and rivers. Therefore, it is important to report estimated total mass loading along with concentration data. The results of the runoff volume, nutrient, and sediment mass loss analysis for the June simulation series are shown in Table 4.4.

Table 4.4. Nutrient and sediment mass loading in runoff for the June rainfall simulation

				June Mass Loss in Runoff					
Rainfall Simulation	Tillage Treatments	**Volume** (L)	**NO_3^-** (mg)	**NH_3** (mg)	**TKN** (mg)	**TN** (mg)	**PO_4^{3-}** (mg)	**TP** (mg)	**TSS** (g)
Run 1- Dry	**CT**	135	209	118	1363	1572	59.5	665	318
		0.93†	0.99	1.2	1.0	1.0	0.90	1.1	1.1
	ST	70.7	65.4	17.1	417	483	56.9	179	79.4
		0.91	0.60	0.66	0.88	0.83	1.0	0.67	0.62
	NT	95.3	275	62.6	810	1085	122	361	130
		0.95	1.2	1.2	1.1	1.1	0.98	1.2	1.2
	p value*	0.6952	0.4332	0.3548	0.4359	0.4544	0.5498	0.3877	0.3203
Run 2 - Wet	**CT**	235	277	129	1782	2058	96.3	898	439
		0.22	0.40	0.67	0.64	0.59	0.26	0.70	0.47
	ST	175	123	52.6	854	977	111	341	189
		0.21	0.69	0.72	0.34	0.38	0.26	0.45	0.33
	NT	134	155	108	752	907	111	225	115
		0.38	0.35	0.50	0.42	0.39	0.39	0.33	0.38
	p value*	0.0911	0.1595	0.4687	0.2514	0.222	0.8449	0.1546	0.0612
Run 3 - Very Wet	**CT**	204a	202	66.5	1386a	1588	103	636a	341a
		0.13	0.16	0.37	0.26	0.24	0.28	0.21	0.21
	ST	160ab	178	44.8	717b	895	107	270b	139b
		0.17	0.69	0.55	0.54	0.57	0.39	0.52	0.45
	NT	114b	75.3	27.9	520b	595	88.3	205b	88.6b
		0.43	0.42	0.66	0.63	0.59	0.52	0.70	0.61
	p value*	0.0213	0.2221	0.1352	0.0413	0.0519	0.7638	0.0017	0.007
	contrast 1*	0.0144	--	--	0.0181	--	--	0.0007	0.0029
	contrast 2*	0.0662	--	--	0.4393	--	--	0.2557	0.2840
	LSD values‡	51.8	--	--	636	--	--	135	112
June Total Mass	**CT**	1720	2063	940	13591	15654	777	6597	3294
		0.43	0.54	0.84	0.62	0.61	0.45	0.68	0.57
	ST	1219	1098	344	5964	7062	824	2369	1222
		0.46	0.75	0.74	0.54	0.56	0.51	0.53	0.51
	NT	1029	1515	594	6248	7762	966	2373	1000
		0.52	1.11	0.88	0.76	0.81	0.65	0.91	0.79

* Significant at the 0.05 level.
† Coefficient of variation indicated under each mean
‡ Fisher's least significant difference values

Examining June Run1 and Run2, the mass loss data indicate there were no statistically significant differences between the tillage treatments for any of the constituents (Table 4.4). Even though the treatments were significantly different regarding the TKN and TSS concentrations, this was not observed when examining the mass losses. The TKN mass loss had the same trend as the TKN concentration in runoff; the CT treatment yielded more TKN mass than the NT treatment, which yielded more than ST. The CT treatment yielded the greatest average TSS mass loss followed by the NT treatment and the ST treatment yielded the least TSS mass.

June Run1: Total Mass

The runoff volume results from June Run1 show that CT yielded 135 L (8.5 mm) of runoff. The NT treatment yielded 95.3 L (6.0 mm), 29 percent less than CT and ST yielded 70.7 L (4.5 mm), 48 percent less than CT. The reason the NT treatment yielded more NO_3^-, NH_3, TKN, TN, PO_4^{3-}, TP, TKN, and TSS mass than the ST treatment may be because NT yielded 26 percent more runoff volume than ST. The differences between the NT and ST treatments were driven by the higher concentrations and higher runoff volume from the NT treatment.

The June Run1 NH_3, TKN, TN and TP mass loss results followed the same trends as the corresponding concentrations in runoff; the ST and NT treatments reduced NH_3 mass by 86 and 47 percent, respectively, than the CT treatment. The ST and NT treatments reduced the TKN mass by 69 and 41 percent, respectively. The TN mass results show that ST reduced the mass lost by 69 percent and NT reduced the mass lost by 31 percent compared to CT. The June Run1 trend for the TP mass showed that compared to CT, the ST and NT treatments reduced the TP mass by 73 and 46 percent, respectively.

The TSS concentration trend from June Run1 showed that the NT reduced the TSS concentration more than ST, however the ST treatment reduced the TSS mass in runoff by 75 percent and the NT treatment reduced the mass by 59 percent, compared to CT.

The CT treatment had the highest average runoff volume and pollutant loading during June Run1, the exception being PO_4^{3-} and NO_3^-. The NT treatment yielded a greater average NO_3^- and a greater average PO_4^{3-} mass loss than CT from June Run1.

The trend for the June Run1 PO_4^{3-} mass loss showed NT yielded more than CT, which yielded more than ST. The June Run1 NO_3^- mass loss trend is the same as the NO_3^- concentration trend; NT yielded more NO_3^- than CT, which yielded more than ST.

June Run2: Total Mass

The June Run2 results show that both conservation tillage treatments, ST and NT, reduced average PO_4^{3-} mass loss by -15 and -16 percent compared to CT. This shows that ST and NT yielded more PO_4^{3-} mass than CT. The increased residue cover on the conservation tillage practices may have contributed nutrients to the runoff. There is potential for dissolved inorganic phosphorous and nitrogen leaching from cover crops (Miller et al., 1994; Barisas et al., 1978). The residue could account for the increased nitrate and phosphate mass in runoff from the conservation tillage practices from June Run1 and increased phosphate from June Run2.

The June Run2 results show that the ST treatment reduced runoff volume by 25 percent, 175 L (11.1 mm), the NT treatment reduced runoff volume by 43 percent, 134 L (8.5 mm), compared to the CT treatment, 235 L (14.9 mm).

The NO_3^- mass loss trend changed from June Run1 to Run2. The NT treatment did not yield the most NO_3^- mass from June Run2. The ST and NT treatments reduced NO_3^- mass by 56 and 44 percent, respectively, compared to CT. The same trend was observed for the June Run2 NH_3 mass results. Compared to CT, the ST and NT treatments reduced NH_3 mass by 59 and 16 percent, respectively. The ST and NT treatments reduced TN mass by 53 and 56 percent, respectively.

The TKN, TP and TSS mass loss results followed the same trend for June Run2 as Run1; the CT treatment yielded more mass than the ST treatment, which yielded more than NT. The TKN mass loss was reduced by 52 percent by ST and by 58 percent by NT compared to CT. The ST and NT treatments reduced TP mass by 62 and 75 percent, respectively, compared to CT. The ST and NT treatments reduced TSS mass by 57 and 74 percent, respectively.

June Run3: Total Mass

Examining June Run3, the mass loss data indicate there were statistically significant differences between the tillage treatments for runoff volume, TKN, TP and TSS, p-values of, 0.0213, 0.0413, 0.0017, and 0.007, respectively (Table 4.4). The Run3

Contrast1 p-values for runoff volume, and TKN, TP and TSS mass losses indicate that the CT treatment yielded significantly greater losses than the average of the ST and NT treatments. The average runoff volume from the ST and NT treatments was 136.9 L (8.7 mm), 33 percent lower than the runoff volume from CT, 204 L (12.9 mm). The average TKN mass lost from the ST and NT treatments was 618.5 mg (392 g ha^{-1}), 55 percent lower than the TKN mass lost from CT, 1386 mg (878 g ha^{-1}). The average TP mass lost from the ST and NT treatments was 237.6 mg (150.4 g ha^{-1}), 63 percent lower than the TP mass lost from CT, 636.3 mg (402.9 g ha^{-1}). The average TSS mass lost from the ST and NT treatments was 113.6 mg (71.9 g ha^{-1}), 67 percent lower than the TSS mass lost from CT, 340.6 mg (215.6 g ha^{-1}). The differences in the TKN and TP mass loss parallel the differences in TSS mass loss. TKN is made up of NH_3 and organic nitrogen, similarly, TP is the combination of PO_4^{3-} and organic phosphorus. There were no significant differences between the treatments regarding NH_3 or PO_4^{3-} mass values for the June simulation series. It is intuitive that the TKN and TP mass loss trends mirror the TSS mass loss trend because fractions of TKN and TP can attach to TSS particles and be transported off the treatments in runoff. It is also intuitive that the significant difference between the treatments regarding runoff volume drives the significant differences regarding some constituents in the runoff.

The June Run3 Contrast 2 was not statistically significant regarding runoff volume, and TKN, TP and TSS mass loss indicating that there was no significant difference between the two conservation tillage treatments, ST and NT. The LSD test from June Run3 for runoff volume indicates that the CT treatment was grouped differently than the NT treatment but not the ST treatment. The LSD test from June Run3 for TKN, TP and TSS mass losses indicate that the CT treatment was grouped differently than the NT and ST treatments.

The trends for NO_3^-, NH_3, and TN showed that the CT treatment yielded more mass than ST, which yielded more mass than NT. This trend was not observed for June Run1 or Run2 for these constituents containing nitrogen. The ST and NT treatments yielded 33 and 58 percent lower NH_3 mass than CT. Compared to CT, the ST and NT treatments reduced NO_3^- mass by 12 and 63 percent, respectively. The ST and NT treatments reduced TN mass by 44 and 62 percent, respectively. The trend for PO_4^{3-} mass loss showed that the ST treatment yielded slightly more mass than CT and more than the NT treatment. No mass loss trends were consistent throughout all June runs.

June Overall: Total Mass

The total runoff volume and nutrient mass loss values are shown at the bottom of Table 4.4. For the June simulation series the CT treatment yielded a total runoff volume of 1720 L (109 mm). The ST and NT treatments reduced the amount of total runoff by 29 and 40 percent, respectively.

The overall June simulation series results for the nitrogen constituents show that the conservation tillage treatments reduced the total mass losses compared to CT. The CT treatment yielded a total NO_3^- mass of 2063 mg (1306 g ha^{-1}). Compared to the CT treatment, ST and NT reduced total NO_3^- mass by 47 and 27 percent, respectively. The CT treatment yielded a total NH_3 mass of 940 mg (595 g ha^{-1}). The ST treatment yielded a 63 percent less NH_3 mass and NT yielded 37 percent less than CT. The CT treatment yielded a total TKN mass of 13.6 g (8605 g ha^{-1}). The ST and NT treatments reduced TKN mass by 56 and 54 percent, respectively. The CT treatment yielded a total TN mass of 15.7 g (9912 g ha^{-1}). Compared to the CT treatment, ST and NT reduced total TN mass by 55 and 50 percent, respectively.

The conservation tillage treatments yielded more total PO_4^{3-} mass from all three June simulation runs. The CT treatment yielded a total PO_4^{3-} mass of 777 mg (492 g ha^{-1}). The ST and NT treatments reduced PO_4^{3-} mass by -6 and -24 percent, respectively. The negative reductions show that CT yielded less PO_4^{3-} total mass than ST and NT treatments. The CT treatment yielded a total TP mass of 6597 mg (4177 g ha^{-1}). Both conservation tillage treatments reduced TP mass by 64 percent, compared to CT.

The CT treatment yielded a total TSS mass of 3294 g (2086 kg ha^{-1}). Compared to the CT treatment, ST and NT reduced total TSS mass by 63 and 70 percent, respectively. The amount of soil eroded from the CT treatment from the three June runs did not exceed the T factor or the acceptable amount of soil loss a soil can handle and still have a high production of crops. The T factor for the Speedwell sandy loam soil is 5 tons ac^{-1} or 11210 kg ha^{-1}. Even though the conservation tillage treatments reduced the soil loss in runoff, the losses from the CT treatment measured for this experiment were not excessive.

4.1.3.2 July Runoff Volume, Nutrients, and Sediment Results

The results of the average runoff volume, nutrient, and sediment concentration analysis for the July simulation series are shown in Table 4.5. The runoff volume data is reported here and discussed in the mass loss results section below. The treatments were not statistically significantly different regarding all constituent concentrations in runoff from the July simulation series.

Table 4.5. Nutrient and sediment concentrations in runoff for the July rainfall simulation

			July Concentration in Runoff						
Rainfall Simulation	Tillage Treatments	**Volume** (L)	**NO_3^-** ($mg\ L^{-1}$)	**NH_3** ($mg\ L^{-1}$)	**TKN** ($mg\ L^{-1}$)	**TN** ($mg\ L^{-1}$)	**PO_4^{3-}** ($mg\ L^{-1}$)	**TP** ($mg\ L^{-1}$)	**TSS** ($mg\ L^{-1}$)
Run 1- Dry	**CT**	278a	2.26	0.28	7.68	9.94	0.47	3.20	1812
		0.53†	0.10	0.33	0.40	0.29	0.13	0.39	0.37
	ST	168b	2.67	0.24	5.22	7.89	0.58	2.06	1324
		0.63	0.29	0.13	0.07	0.14	0.14	0.10	0.30
	NT	114b	2.61	0.26	6.37	8.98	0.74	1.90	1039
		0.74	0.16	0.47	0.28	0.20	0.22	0.22	0.23
	p value*	0.0157	0.6460	0.8667	0.5265	0.6031	0.1068	0.2428	0.2930
	contrast 1*	0.0075	--	--	--	--	--	--	--
	contrast 2*	0.1659	--	--	--	--	--	--	--
	LSD values‡	88.2	--	--	--	--	--	--	--
Run 2 - Wet	**CT**	319.8a	2.11	0.28	8.02	10.1	0.67	3.01	1852
		0.32	0.06	0.15	0.56	0.46	0.23	0.55	0.60
	ST	204.0b	2.00	0.28	4.48	6.47	0.74	1.63	1158
		0.11	0.19	0.12	0.03	0.06	0.13	0.04	0.30
	NT	129.1b	1.82	0.32	4.43	6.25	0.83	1.34	844
		0.29	0.20	0.24	0.26	0.24	0.09	0.16	0.18
	p value*	0.0161	0.2974	0.7862	0.3021	0.2741	0.2813	0.2057	0.3599
	contrast 1*	0.0084	--	--	--	--	--	--	--
	contrast 2*	0.1101	--	--	--	--	--	--	--
	LSD values‡	102	--	--	--	--	--	--	--
Run 3 - Very Wet	**CT**	307a	1.95	0.33	5.64	7.59	0.58	2.73	1845
		0.29	0.06	0.30	0.46	0.36	0.20	0.49	0.51
	ST	206b	1.80	0.27	3.62	5.42	0.76	1.39	1117
		0.03	0.11	0.05	0.19	0.15	0.26	0.26	0.27
	NT	146b	1.73	0.31	3.61	5.34	0.80	1.24	980
		0.31	0.08	0.11	0.15	0.12	0.10	0.28	0.15
	p value*	0.0278	0.2330	0.3845	0.2447	0.2129	0.1438	0.0828	0.2119
	contrast 1*	0.0141	--	--	--	--	--	--	--
	contrast 2*	0.1766	--	--	--	--	--	--	--
	LSD values‡	101	--	--	--	--	--	--	--

* Significant at the 0.05 level.
† Coefficient of variation indicated under each mean
‡ Fisher's least significant difference values

July Run1: Concentration

The trend observed for July Run1 showed that the ST treatment reduced the NO_3^- concentration by -18 percent compared to CT and the NT treatment reduced the NO_3^- concentration by -16 percent (Table 4.5). These negative reductions indicate that the conservation tillage treatment yielded a higher NO_3^- concentration than the CT treatment. The PO_4^{3-} concentration results for July Run1 show the same trend. The ST and NT treatments reduced PO_4^{3-} concentration by -22 and -56 percent, respectively, compared to CT. This shows that the NT treatment yielded a greater PO_4^{3-} concentration than ST, which was greater than the concentration from CT.

The trends regarding NH_3, TKN, and TN were similar; the concentration from the CT treatment was greater than that from NT, which was greater than the concentration from ST. The ST and NT treatments reduced NH_3 concentration by 14 and 7 percent, respectively, compared to CT. The ST treatment reduced the TKN concentration by 32 percent and NT reduced the TKN concentration by 17 percent, compared to CT. The TN concentration results show that ST and NT reduced the concentration by 21 and 10 percent, respectively.

The trends observed for TP and TSS from July Run1 showed that the CT yielded a greater concentration than ST, which yielded a greater concentration than the NT treatment. Compared to CT, the ST and NT treatments reduced the TP concentration in runoff by 36 and 40 percent, respectively. The ST and NT treatments reduced TSS concentration by 27 and 43 percent, respectively, compared to CT.

July Run2: Concentration

The trends observed from July Run2 show that NO_3^-, TKN, TN, TP and TSS average concentrations were greater from the CT treatment than ST, which yielded a greater concentration than the NT treatment (Table 4.5). The NO_3^- concentration results show that ST and NT reduced the concentration compared to CT by 5 and 14 percent, respectively. The ST and NT treatments reduced TKN concentration by 44 and 45 percent, respectively, compared to CT. The ST and NT treatments reduced the TN concentration by 36 and 38 percent, respectively. The trend observed regarding TP concentration showed that the ST treatment yielded a 46 percent lower concentration and

NT yielded a 56 percent lower concentration than CT. Compared to CT, the ST and NT treatments reduced TSS concentrations by 37 and 54 percent, respectively.

The trend regarding the NH_3 concentration showed that the NT treatment yielded higher concentrations than CT, which yielded an equal concentration as ST. The NT treatment reduced NH_3 concentration by -12 percent compared to CT. Like the trend seen for July Run1 PO_4^{3-} concentration results, the July Run2 trend shows that the conservation tillage treatments yielded higher PO_4^{3-} concentrations than CT.

July Run3: Concentration

For July Run3, the ST and NT treatments reduced the NO_3^-concentration by 8 and 11 percent, respectively, compared to CT. The ST and NT treatments reduced the NH_3 concentration by 17 and 5 percent, respectively, compared to CT. Compared to CT, the conservation tillage treatments both reduced the TKN concentration by 36 percent. The ST and NT treatments reduced the TN concentration by 29 and 30 percent, respectively. The trend observed regarding TP concentration showed that the ST treatment yielded a 49 percent lower concentration than CT; the ST treatment yielded a 54 percent lower concentration. The ST and NT treatments reduced the TSS concentration by 39 and 47 percent, respectively. The NT treatment yielded greater PO_4^{3-} concentration than the ST and CT treatments. The NT treatment reduced the PO_4^{3-} concentration by -38 and the ST reduced the concentration by -31 percent.

A trend throughout the July runs regarding PO_4^{3-} concentration was observed. The PO_4^{3-} concentration from NT was greater than ST, which was greater than CT, although this trend was not found significant. A trend for the TP and TSS concentration results was observed throughout July: the average concentration from CT was greater than ST, which was greater than NT.

June and July Simulation Series: Concentration

A trend for orthophosphate concentration was observed over both simulation series. The no-till treatment yielded consistently greater average concentration of PO_4^{3-} concentration than ST, from 5 to 32 percent more, and the CT treatment, from 28 to 56 percent more. Although this observation was not statistically significant in every run, the conservation tillage practices contained more rye residue cover, which may be the source of soluble phosphorus throughout the rainfall simulations.

July Total Mass

The results of the runoff volume, nutrient, and sediment mass loss analysis for the July simulation series are shown in Table 4.6.

Table 4.6. The results of nutrient and sediment mass in runoff for the July rainfall simulation

		July Mass Loss in Runoff							
Rainfall Simulation	Tillage Treatments	**Volume** (L)	**NO_3^-** (mg)	**NH_3** (mg)	**TKN** (mg)	**TN** (mg)	**PO_4^{3-}** (mg)	**TP** (mg)	**TSS** (g)
Run 1- Dry	**CT**	278a	609a	78.2	2127	2736a	128	973	524
		0.53†	0.47	0.77	0.65	0.60	0.45	0.67	0.69
	ST	168b	478a	40.2	912	1390ab	100	369	212
		0.63	0.80	0.55	0.66	0.71	0.70	0.76	0.87
	NT	114b	319b	31.8	602	922b	91.6	210	102
		0.74	0.89	0.98	0.71	0.77	0.86	0.74	0.63
	p value*	0.0157	0.0126	0.0988	0.0691	0.0449	0.059	0.069	0.0793
	contrast 1*	0.0075	0.0092	--	--	0.0202	--	--	--
	contrast 2*	0.1659	0.037	--	--	0.3919	--	--	--
	LSD values‡	88.2	143	--	--	1356	--	--	--
Run 2 - Wet	**CT**	320a	682a	83.2	2430	3112	205	1031	624
		0.32	0.36	0.41	0.65	0.58	0.40	0.67	0.68
	ST	204b	412b	57.1	868	1281	149	327	199
		0.11	0.28	0.20	0.10	0.15	0.23	0.10	0.13
	NT	129b	243b	37.5	526	770	109	178	92.6
		0.29	0.49	0.16	0.40	0.42	0.31	0.40	0.20
	p value*	0.0161	0.0100	0.0716	0.1116	0.0837	0.0586	0.1023	0.1223
	contrast 1*	0.0084	0.0052	--	--	--	--	--	--
	contrast 2*	0.1101	0.0835	--	--	--	--	--	--
	LSD values‡	102	205	--	--	--	--	--	--
Run 3 - Very Wet	**CT**	307a	603a	105	1848	2451	179a	907	583
		0.29	0.33	0.51	0.60	0.53	0.37	0.61	0.62
	ST	206b	317b	55.6	729	1100	155ab	283	199
		0.03	0.13	0.07	0.21	0.17	0.28	0.27	0.35
	NT	146b	256b	44.7	503	758	121b	191	116
		0.31	0.38	0.40	0.46	0.43	0.38	0.48	0.50
	p value*	0.0278	0.0239	0.1008	0.0919	0.0721	0.0307	0.0718	0.0819
	contrast 1*	0.0141	0.0115	--	--	--	0.0239	--	--
	contrast 2*	0.1766	0.2012	--	--	--	0.0664	--	--
	LSD values‡	101	210	--	--	--	37.4	--	--
July Total Mass	**CT**	2715	5680	800	19218	24898	1536	8729	5194
		0.34	0.34	0.51	0.57	0.51	0.40	0.57	581.26
	ST	1732	3784	459	7529	11313	1212	2935	1827
		0.30	0.49	0.29	0.39	0.42	0.38	0.47	0.49
	NT	1168	2454	342	4895	7349	965	1736	932
		0.41	0.61	0.50	0.49	0.53	0.47	0.51	0.44

* Significant at the 0.05 level.
† Coefficient of variation indicated under each mean
‡ Fisher's least significant difference values

The July data results show that there were statistically significant differences between the tillage treatments for runoff volume from Run1, Run2 and Run3 with p-values of 0.0157, 0.0161, and 0.0278, respectively (Table 4.6). All Contrast1 p-values for runoff volume indicated that the CT treatment yielded a significantly greater runoff volume than the average of the ST and NT treatments. The average runoff volume from July Run1 from the ST and NT treatments, 140.8 L (8.9 mm), was 49 percent lower than the average runoff volume from CT, 278.5 L (17.6 mm). The ST and NT treatments average 166.6 L (10.5 mm) of runoff volume from July Run2, which was 48 percent lower than the average runoff volume from CT, 319.8 L (20.2 mm). The average runoff volume from July Run3 from the ST and NT treatments, 176.0 L (11.1 mm), was 42 percent lower than the average runoff volume from the CT treatment, 306.6 L (19.4 mm). The Run1 Contrast 2 was not found statistically significant for the July simulation runs indicating that there in no significant difference between the two conservation tillage treatments, ST and NT, regarding runoff volume.

The LSD grouping from July Runs 1, 2 and 3 show that the CT treatment was grouped differently than the NT and ST treatment regarding runoff volume. The conventional tillage treatment yielded greater averages of runoff volume and was grouped alone. This result strengthens the Contrast1 result.

The tillage treatments were statistically different with regards to NO_3^- mass lost from July Run1, Run2 and Run3 with p-values of 0.0126, 0.01, 0.0239, respectively (Table 4.6). The Contrast1 p-values for NO_3^- mass loss indicate that the CT treatment yielded a statistically significantly greater NO_3^- mass loss than the average of the ST and NT treatments for all July runs. For July Run1, the average NO_3^- mass lost from the ST and NT treatments was 398.7 mg (252.4 g ha^{-1}), 34 percent lower than the NO_3^- mass lost from CT, 609.0 mg (385.6 g ha^{-1}). The average NO_3^- mass lost from the ST and NT treatments for July Run2 was 327.6 mg (207.4 g ha^{-1}), 52 percent lower than the NO_3^- mass lost from CT, 681.7 mg (431.6 g ha^{-1}). For July Run3, the average NO_3^- mass lost from the ST and NT treatments was 286.4 mg (181.3 g ha^{-1}), 53 percent lower than the NO_3^- mass lost from CT, 602.6 mg (381.5 g ha^{-1}).

The LSD grouping from July Run1 show that the CT and ST treatments were grouped differently than the NT regarding NO_3^- mass lost. The CT and ST treatments yielded greater averages of NO_3^- mass lost and were grouped together. The LSD grouping from July Run2 and Run3 show that NT and ST treatments were grouped differently than the CT regarding NO_3^- mass lost. The CT treatment yielded a greater average of NO_3^- mass lost than the NT and ST treatments.

July Run1: Total Mass

The tillage treatments were statistically different regarding the TN mass lost in runoff with a p-value of 0.0449. The Contrast1 p-values for TN mass loss indicate that the CT treatment yielded a statistically significantly greater TN mass loss than the average of the ST and NT treatments for July Run1. The average TN mass lost from the ST and NT treatments was 1156 mg (732 g ha^{-1}), 58 percent lower than the TN mass lost from CT, 2736 mg (1732 g ha^{-1}). The LSD grouping from July Run1 show that the CT treatment was grouped differently than the NT regarding TN mass in runoff.

Although the treatments were not significantly different from July Run1 regarding NH_3, TKN, PO_4^{3-}, TP and TSS mass loss, the trends were the same (Table 4.6). The CT treatment yielded a greater mass of these constituents than ST, which yielded a greater mass than NT. The CT treatment yielded greater NH_3 mass than ST and NT by 49 and 59 percent, respectively. The CT treatment yielded a 57 percent greater TKN mass than ST and 72 percent greater than the NT treatment. The July Run1 was the first occurrence that the CT treatment yielded a greater PO_4^{3-} mass than ST, by 22 percent and NT, by 28 percent. The trend observed regarding TP mass showed that the CT treatment yielded a 62 percent greater mass than ST and a 78 percent greater mass than NT. The CT treatment yielded a greater TSS concentration than ST and NT by 60 and 81 percent, respectively. The variability of the data may have masked the statistical differences between the treatments regarding these constituents.

July Run2: Total Mass

The treatments were not significantly different regarding NH_3, TKN, TN, PO_4^{3-}, TP and TSS mass loss from July Run2, however the trends were the same as July Run1 (Table 4.6). The ST treatment yielded a 31 percent lower NH_3 mass than CT and the NT treatment yielded a 55 percent lower NH_3 mass. The ST and NT treatments reduced TKN mass by 64 and 78 percent, respectively. The conservation tillage treatments reduced the TN mass, 59 percent by ST and 75 percent by NT. Compared to CT, the ST treatment reduced the PO_4^{3-} mass by 27 percent and NT reduced the mass by 47 percent. The ST and NT treatments reduced TP mass by 68 and 83 percent, respectively. The ST and NT treatments reduced TSS mass by 68 and 85 percent, respectively. This trend was observed for TKN, TP and TSS mass loss from the June Run2 results.

July Run3: Total Mass

The July Run3 mass loss results show that there were statistically significant differences between the tillage treatments with regards to PO_4^{3-} mass loss with a p-value of 0.0307 (Table 4.6). The Contrast1 p-value for PO_4^{3-} mass loss for July Run3 indicates that the CT treatment lost significantly more PO_4^{3-} mass than the average of the ST and NT treatments. The average PO_4^{3-} mass lost from the ST and NT treatments was 137.9 mg (87.3 g ha^{-1}), 23 percent lower than the PO_4^{3-} mass lost from CT, 179.3 mg (113.5 g ha^{-1}). The Run3 Contrast2 was not significant, indicating that there were no differences between the PO_4^{3-} mass results from the conservation tillage practices, ST and NT.

The LSD grouping from July Run2 and Run3 show that CT and NT treatments were grouped differently regarding NO_3^- mass lost and the ST treatment fell in either group. The CT treatment yielded a greater average of NO_3^- mass lost than the NT.

The trends were the same from July Run3 regarding NH_3, TKN, TN, PO_4^{3-}, TP and TSS mass loss, although the treatments were not significantly different (Table 4.6). The CT treatment yielded greater mass than ST, which yielded greater mass than NT. The ST and NT treatments reduced NH_3 mass by 47 and 58 percent, respectively. Compared to CT, the ST and NT treatments reduced the TKN mass by 61 and 73 percent, respectively. The TN mass results show that ST reduced the mass loss by 55 percent and NT reduced the mass loss by 69 percent. The ST and NT treatments reduced PO_4^{3-} mass by 14 and 32 percent, respectively. Compared to CT, the ST and NT treatments reduced the TP mass by 69 and 79 percent, respectively. The TSS mass results show that ST reduced the mass loss by 66 percent and NT reduced the TSS mass loss by 80 percent. The same trends for NH_3, TKN, TP and TSS mass losses were observed from June Run3.

July Overall: Total Mass

A trend where, CT yielded more mass than ST, which yielded more mass than NT, was observed for every constituent for all July runs. The trends throughout the June runs were not as consistent as the July trends. It appears that as the residue cover decays over time the contributions of nitrogen and phosphorus are less and have a lower impact on the mass loss results from the conservation tillage treatments.

The July series results for PO_4^{3-} were unlike the results from June. June showed NT and ST treatments resulted in higher mass loading while July showed CT yielded more PO_4^{3-}. The CT treatment yielded a total PO_4^{3-} mass of 1536 mg (973 g ha^{-1}). The ST and NT treatments reduced PO_4^{3-} mass by 21 and 37 percent, respectively. The CT treatment yielded a total TP mass of 8,729 mg (5,527 g ha^{-1}). The ST and NT treatments reduced the total TP mass in runoff by 66 and 80 percent, respectively.

The total runoff volume and nutrient mass loss values from the July simulation series are shown at the end of Figure 4.6. For the entire July simulation series the CT treatment yielded a total runoff volume of 2,715 L (172 mm). The ST and NT treatments reduced the amount of total runoff by 36 and 57 percent, respectively.

The July total mass results show that the conservation tillage treatments reduced the total mass losses compared to CT. The CT treatment yielded a June total NO_3^- mass of 5,680 mg (3,596 g ha^{-1}). Compared to the CT treatment, ST and NT reduced total NO_3^- mass by 33 and 57 percent, respectively. The CT treatment yielded a June total NH_3 mass of 800 mg (507 g ha^{-1}). The ST treatment yielded a 43 percent less NH_3 mass and NT yielded 57 percent less than CT. The CT treatment yielded a June total TKN mass of 19.2 g (12.2 kg ha^{-1}). The ST and NT treatments reduced TKN mass by 61 and 75 percent, respectively. The CT treatment yielded a June total TN mass of 24.9 g (15.8 kg ha^{-1}). Compared to the CT treatment, ST and NT reduced total TN mass by 55 and 70 percent, respectively.

The conservation tillage treatments reduced the total suspended solids mass from the June simulation series. The CT treatment yielded a total TSS mass of 5,194 g (3,289 kg ha^{-1}). Compared to the CT treatment, ST and NT reduced total TSS mass by 65 and 82 percent, respectively. Comparing the sediment loss from the CT treatment to the T factor shows that the CT treatment yields an acceptable sediment loss. Even though the conservation tillage treatments reduced the soil loss in runoff, the losses from the CT treatment are reasonable for the burley tobacco field.

4.1.3.3 Overall Total Runoff Volume, Nutrients, and Sediment Mass Results

The trend that developed from June Run2 through July Run3 was CT yielded greater runoff volume than ST, which yielded more than NT. The treatments were often significantly different regarding the runoff volume and had this trend (June Run3, July Run1, Run2 and Run3). The impact of this trend regarding runoff volume is shown in the differences between the concentration and total mass results. A total of 174 mm of rainfall was simulated for all six runs. The total average runoff from the CT treatment was 93.6 mm (1478 L) (Table 4.7). The strip tillage treatment yielded 62.3 mm (33% less runoff), and no-till yielded 46.4 mm (50% less runoff).

The CT treatment yielded more mass of all constituents in runoff than NT and ST (Table 4.7). The no-till treatment was superior to ST in reducing pollutant mass, except regarding NH_3 mass. The strip tillage treatment reduced NH_3 mass by 54 percent and NT reduced it by 46 percent.

Table 4.7 Percent reductions of pollutant mass in runoff from conservation tillage practices

Tillage Treatments	Total Runoff (mm)	Total Mass per area						
		NO_3^- (kg ha^{-1})	NH_3 (kg ha^{-1})	TKN (kg ha^{-1})	TN (kg ha^{-1})	PO_4^{3-} (kg ha^{-1})	TP (kg ha^{-1})	TSS (kg ha^{-1})
CT	281	4.90	1.10	20.8	25.7	1.46	9.70	5374
	Percent less than CT							
ST	33	37	54	59	55	12	65	64
NT	50	49	46	66	63	17	73	77

4.1.3.4 Pesticide Surface Runoff Results: June Series

With respect to pesticide concentration and mass loss in the runoff, there were no statistically significant differences between treatments for the June simulation series (Table 4.8). The CT treatment yielded the highest average concentration and mass of both chlorpyrifos and flumetralin across all June runs, except June Run1 when the ST treatment yielded a greater average concentration of flumetralin.

Table 4.8. Pesticide concentration and mass loss in surface runoff for June rainfall simulation series

		June				
		Pesticide Loss in Runoff				
Rainfall Simulation	Tillage Treatments	**Chlorpyrifos** ($\mu g\ L^{-1}$)	**Flumetralin** ($\mu g\ L^{-1}$)	**Volume** (L)	**Chlorpyrifos** (μg)	**Flumetralin** (μg)
Run 1- Dry	**CT**	0.657	0.0479	135	127	3.33
		0.70†	0.86	0.93	1.4	0.45
	ST	0.309	0.0592	70.7	20.5	2.35
		0.14	0.93	0.91	0.82	0.57
	NT	0.253	0.0124	95.3	33.7	0.387
		0.63	1.3	0.95	1.3	0.92
	p value*	0.1560	0.5400	0.6950	0.4170	0.1410
Run 2 - Wet	**CT**	0.10	--§	235	24.4	--
		0.65		0.22	0.74	
	ST	0.069	--	175	12.5	--
		0.62		0.21	0.77	
	NT	0.025	--	134	3.53	--
		0.28		0.38	0.61	
	p value*	0.3310	--	0.0910	0.2630	--
Run 3 - Very Wet	**CT**	0.097	--	204a	20.6	--
		0.46		0.13	0.56	
	ST	0.022	--	160ab	3.66	--
		1.1		0.17	1.2	
	NT	0.034	--	114b	4.95	--
		1.0		0.43	1.3	
	p value*	0.0730	--	0.0210	0.0690	--
	LSD values‡	--	--	51.8	--	--
June Total Mass	**CT**			1720	517	10
				0.43	1.8	0.45
	ST			1219	110	7
				0.46	1.0	0.57
	NT			1029	127	1
				0.52	1.9	0.92

* Significant at the 0.05 level.
† Coefficient of variation indicated under each mean
‡ Fisher's least significant difference values
§ Pesticide not detected or was below detection limit, 0.3 $\mu g\ L^{-1}$

June Run1

For June Run1, the ST and NT treatments reduced the chlorpyrifos concentration by 53 and 61 percent, respectively, compared to CT (Table 4.8). The higher chlorpyrifos concentration and greater average runoff volume made the CT treatment yield a greater chlorpyrifos mass than the other treatments. The ST and NT treatments reduced the chlorpyrifos mass by 84 and 74 percent, respectively. The ST treatment yielded higher flumetralin concentration than both CT and NT. The flumetralin mass results show that the ST treatment yielded 29 percent less mass than CT and NT yielded 88 percent less mass.

June Run2

Regarding the June Run2 results, The ST and NT treatments reduced the chlorpyrifos concentration by 31 and 75 percent, respectively. The CT treatment yielded higher chlorpyrifos mass than both ST and NT. The ST treatment reduced chlorpyrifos mass by 49 and the NT treatment reduced mass by 86 percent. Flumetralin was not detected in the June Run2 samples.

June Run3

The CT treatment yielded a higher chlorpyrifos concentration and mass than the conservation tillage treatments. The ST and NT treatments reduced the chlorpyrifos concentration by 77 and 65 percent, respectively. The chlorpyrifos mass results show that the ST and NT treatments yielded 82 and 86 percent less chlorpyrifos mass than the CT treatment, respectively.

Flumetralin was not detected in samples from June Run2 and Run3. The flumetralin herbicide was applied on 24 July during the year prior to the study, which explains the low levels of flumetralin in the runoff results.

The pesticide chlorpyrifos adsorbs strongly to soil particles. The increased tillage operations preformed on the CT treatment loosened soil, which was then more susceptible to erosive forces. There is a trend between the mass of TSS and chlorpyrifos lost in runoff from the June Run1 and Run2 (Figure 4.1). The June Run3 results show that while the ST treatment yielded more TSS mass, the NT treatment yielded more chlorpyrifos mass in runoff.

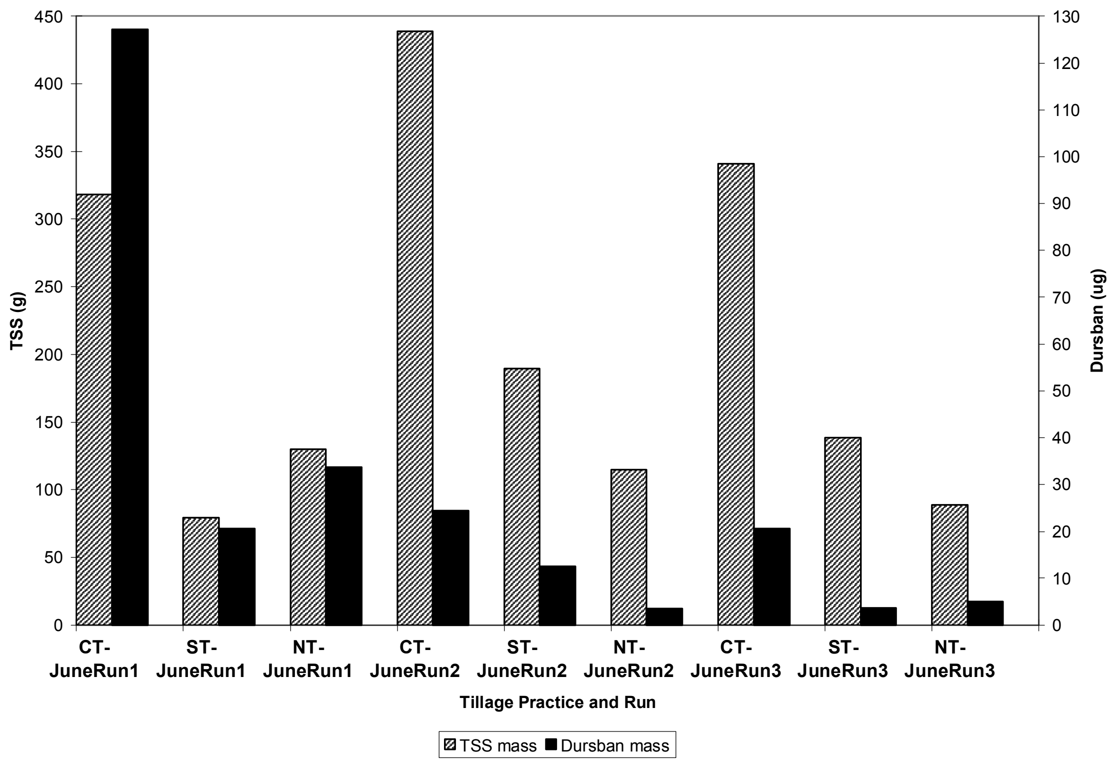


Figure 4.1 The chlorpyrifos and TSS mass loss from the June simulation series

4.1.3.5 Pesticide Surface Runoff Results: July Series

There were no statistically significant differences in pesticide concentration or mass loss between the three tillage treatments for the July rainfall simulation series (Table 4.9).

Table 4.9. The statistical results of pesticide mass in runoff for the July rainfall simulation

		July Pesticide Loss in Runoff				
Rainfall Simulation	Tillage Treatments	**Chlorpyrifos** ($\mu g\ L^{-1}$)	**Flumetralin** ($\mu g\ L^{-1}$)	**Volume** (L)	**Chlorpyrifos** (μg)	**Flumetralin** (μg)
Run 1- Dry	**CT**	0.18	--§	278a	60.9	--
		0.53†		0.53	0.97	
	ST	0.088	--	168b	13.4	--
		0.24		0.63	0.40	
	NT	0.062	--	114b	8.10	--
		0.33		0.74	1.0	
	p value*	0.1257	--	0.0157	0.1745	--
	LSD values‡	--	--	88.2	--	--
Run 2 - Wet	**CT**	0.14	--	320a	38.7	--
		0.84		0.32	0.49	
	ST	0.13	0.0073	204b	23.9	1.58
		1.6	0.56	0.11	1.6	0.56
	NT	0.042	0.0079#	129b	6.67	0.96#
		1.3	0.00	0.29	1.5	0.0
	p value*	0.5863	--	0.0161	0.3114	--
	LSD values‡	--	--	102	--	--
Run 3 - Very Wet	**CT**	0.19	0.011#	307a	66.61	2.28#
		0.84	0.0	0.29	0.95	0.0
	ST	0.021	0.001#	206b	4.43	2.08#
		0.64	0.0	0.03	0.65	0.0
	NT	0.036	0.013#	146b	5.54	2.57#
		0.62	0.0	0.31	0.68	0.0
	p value*	0.1260	--	0.0278	0.1525	--
	LSD values‡	--	--	101	--	--
July Total Mass	**CT**			2715	499	2.28
				0.34	0.8	0.0
	ST			1732	125	5.24
				0.30	1.5	0.37
	NT			1168	61.0	3.54
				0.41	1.0	0.64

* Significant at the 0.05 level.
† Coefficient of variation indicated under each mean
‡ Fisher's least significant difference values
§ Pesticide not detected or was below detection limit, 0.3 $\mu g\ L^{-1}$
# Pesticide detected in only one sample

July Run1

For July Run1, the ST and NT treatments reduced the chlorpyrifos concentration by 52 and 67 percent, respectively, compared to the CT treatment. This was the same trend for chlorpyrifos concentration observed from June Run1 (Table 4.9). Compared to CT, the ST and NT treatments reduced the chlorpyrifos mass loss by 38 and 83 percent, respectively. Flumetralin was not detected in the July Run1 samples.

July Run2

The July Run2 results show that the ST and NT treatments reduced the chlorpyrifos concentration in runoff by 8 and 71 percent, respectively. This trend was also shown in the chlorpyrifos mass results. The chlorpyrifos concentration and mass trends were the same as the June Run2 chlorpyrifos trends. The ST treatment yielded a slightly higher flumetralin concentration than both NT and the CT treatment, where flumetralin was not detected. The flumetralin mass results show that the ST treatment yielded more mass than the NT treatment.

July Run3

The ST and NT treatments reduced the chlorpyrifos concentration in runoff by 89 and 81 percent, respectively, for the July Run3 results. Compared to CT, the ST and NT treatments reduced the chlorpyrifos mass loss by 93 and 92 percent, respectively. While no statistical differences were detected, the large relative differences between treatments illustrate a high degree of variability in the data. The chlorpyrifos concentration and mass trends from July Run3 are similar to the trends observed from June Run3. The flumetralin concentration and mass results show that the NT treatment yielded greater concentration than CT and ST. The ST and NT treatments reduced the flumetralin mass by 9 and -13 percent, respectively. This shows that the NT treatment yielded higher flumetralin mass than the other treatments.

Flumetralin was not detected from June Run2, June Run3 and July Run1 runoff samples and was detected in only a few samples from July Run2 and Run3. The detection of flumetralin in later run samples is unexpected because flumetralin was not reapplied to the field before July Run2 or Run3.

The overall trend throughout the June and July simulation series showed that the CT treatment yielded greater chlorpyrifos concentration and mass.

The chlorpyrifos may have been attached to soil or organic matter particles present in the TSS. Figure 4.2 shows the similar trends between TSS mass loss and chlorpyrifos mass loss for the July simulation series.

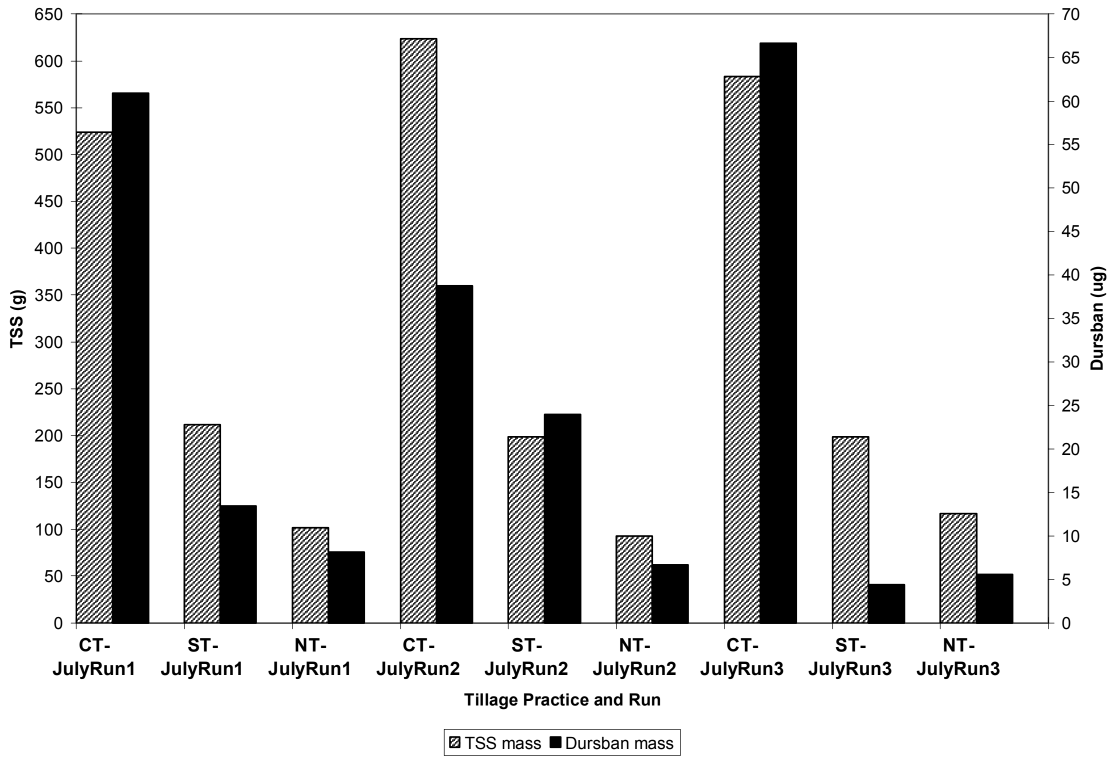


Figure 4.2 The chlorpyrifos and TSS mass loss from the July simulation series

4.1.3.6 Summary of Pesticides in Runoff Results

Total chlorpyrifos mass lost from conventional tillage was 1,015 µg (643 mg ha^{-1}) from all simulations (Table 4.10). The strip tillage treatment yielded 77 percent less, and no-till yielded 82 percent less chlorpyrifos mass loss compared to the CT treatment. The conventional tillage treatment lost 12.3 µg (7.77 mg ha^{-1}) of flumetralin in runoff. Compared to CT, the no-till treatment resulted in 62 percent less flumetralin in runoff. Strip tillage yielded the same amount of flumetralin as the CT treatment. It is important to note, however, at such low quantities these rainfall events were not significant in the loss of flumetralin. The amount of chlorpyrifos and flumetralin lost per tillage treatment accounted for less than 1 percent of the quantities applied.

Table 4.10 Percent reductions of pesticide mass in runoff from conservation tillage practices

Tillage Treatments	Total Runoff (mm)	Total Mass per area: Chlorpyrifos (mg ha^{-1})	Flumetralin (mg ha^{-1})
CT	281	643	7.77
	Percent less than CT		
ST	33	77	0
NT	50	82	62

4.1.4 Lysimeter Sample Results

4.1.4.1 Nutrients in Percolated Water

The average concentration results for nutrients in the soil water from the June and July simulation series are shown in Table 4.11.

Table 4.11. The results of nutrient concentration in soil water for each series

		Average Concentration of Constituent in Soil Water					
Rainfall Simulation	Tillage Treatments	**NO_3^-** (mg L^{-1})	**NH_3** (mg L^{-1})	**TKN** (mg L^{-1})	**TN** (mg L^{-1})	**PO_4^{3-}** (mg L^{-1})	**TP** (mg L^{-1})
June	**CT**	5.12	1.49	4.61	8.19	0.16	0.084
		0.76†	0.91	0.10	0.20	1.1	0.50
	ST	2.27	0.85	3.42	5.69	0.18	0.031
		0.58	1.04	0.49	0.52	0.55	0.84
	NT	2.24	0.32	0.91	2.85	0.11	0.011
		1.2	0.88	0.63	0.80	1.1	0.10
	p value*	0.2651	0.4246	0.2370	0.0912	0.4887	0.1312
	LSD values‡	--	--	--	--	--	--
July	**CT**	7.40	0.22	0.60	8.00	0.55	0.14
		0.00	0.00	0.54	1.49	0.00	0.01
	ST	8.88	0.23	0.77	9.65	0.28	0.23
		0.17	0.12	0.42	0.14	0.17	0.24
	NT	8.72	0.21	0.76	9.48	0.38	0.18
		0.22	0.05	0.74	0.18	0.48	0.47
	p value*	0.9916	0.7343	0.9858	0.3229	0.6413	0.5786
	LSD values‡	--	--	--	--	--	--

* Significant at the 0.05 level.
† Coefficient of variation indicated under each mean
‡ Fisher's least significant difference values, missing values due to unequal sample number

The total mass of nutrients in soil water was calculated using the estimated percolated water volume from each treatment. The percolated volume amount and the total mass of constituents in percolated water results are shown in Table 4.12.

Table 4.12 The results of nutrient total mass in soil water for each series

Rainfall Simulation	Tillage Treatments	Percolated Volume (L)	Total Mass of Constituent in Soil Water NO3- (mg)	NH3 (mg)	TKN (mg)	TN (mg)	PO43- (mg)	TP (mg)
June	**CT**	118b	468	214	654	904	13.5	11.0a
		0.50†	0.29	1.3	0.26	0.29	0.74	0.15
	ST	134b	398	113	457	760	24.8	4.57b
		0.02	0.57	1.03	0.48	0.51	0.55	0.73
	NT	239a	303	61.9	263	573	20.1	3.05b
		0.33	0.89	0.48	0.66	0.53	0.91	0.06
	p value*	0.0503	0.6751	0.6450	0.5027	0.6262	0.2119	0.0114
	LSD values‡	97.6	--	--	--	--	--	--
July	**CT**	166b	2545	75.7	128	3241	189	35.7
		1.0	0.00	0.00	0.01	1.29	0.00	0.55
	ST	344ab	3010	80.7	266	5735	99.1	78.7
		0.13	0.05	0.24	0.44	0.01	0.28	0.17
	NT	519a	4546	110	364	7342	201	92.6
		0.16	0.32	0.13	0.62	0.25	0.55	0.44
	p value*	0.0179	0.3477	0.1161	0.5224	0.1550	0.4552	0.4058
	LSD values‡	193	--	--	--	--	--	--

* Significant at the 0.05 level.
† Coefficient of variation indicated under each mean
‡ Fisher's least significant difference values, missing values due to unequal sample number

June: Nutrients in Soil Water

The conventional tillage treatment had the largest mean concentrations of NO_3^-, NH_3, TKN, and TP from the June simulation series. The strip tillage treatment had the largest mean concentration of PO_4^{3-}. The concentration of NO_3^- in the soil water from each treatment in June was below the EPA drinking water standard, 10 mg L^{-1}.

The percolated volume and TP mass lost from the June simulation series were statistically different with p-values of 0.05 and 0.01, respectively. The LSD test for the June simulation series for percolated water volume shows that the NT treatment was grouped alone and the CT and ST treatments were grouped together. The NT treatment yielded significantly greater volume of percolated water than the other treatments. The no-till treatment yielded 238.7 L (15.1 mm) of percolated water volume, the CT treatment yielded 118.3 L (7.5 mm), and ST yielded 134.4 L (8.5 mm). The increased amount of residue cover on the NT treatment held water and allowed for greater infiltration than the other treatments. The LSD test for the June simulation series for percolated water volume shows that the CT and ST treatments were grouped together. The CT treatment yielded significantly greater TP mass than the other treatments. The TP mass lost to deep percolation during June from CT was 11.0 mg (6.96 g ha^{-1}), ST yielded 4.57 mg (2.89 g ha^{-1}), and NT yielded 3.05 mg (1.93 g ha^{-1}). Phosphorus adsorbs to soil particles and remains in the soil matrix unless the soil is saturated with phosphorus.

Even though the CT treatment had significantly less percolated water than the NT treatment the greatest mass losses of NO_3^-, NH_3, TKN, and TN were from the CT treatment. Although NT had the most percolated water, this practice had the least average mass of all constituents, except PO_4^{3-}, lost to deep percolation. The NT treatment yielded 33 percent more PO_4^{3-} mass in percolated water than CT, but 19 percent less than the ST treatment.

July: Nutrients in Soil Water

For the July simulation series, the conventional tillage treatment had the highest average concentration of PO_4^{3-}. The strip tillage treatment had the highest average NO_3^-, NH_3, TKN, TN, and TP concentrations. It is important to note that the concentration of NO_3^- in the soil water from each treatment in July was below the EPA drinking water standard, 10 mg L^{-1}.

Examining the July simulation series results, the treatments were statistically different regarding percolated water volume with a p-value of 0.02. The LSD test for the July simulation series for percolated water volume shows that the CT and ST treatments were grouped together. The NT treatment produced the greatest volume of leachate. The no-till treatment yielded 518.6 L (32.8 mm) of percolated water followed by ST with 343.5 L (21.7 mm) and the CT treatment had the least with 165.7 L (10.5 mm).

The NT treatment contributed the highest NO_3^- NH_3, TKN, TN, PO_4^{3-} and TP mass loss in soil water after the July simulations. Even though the NT treatment yielded lower concentrations of these constituents, it yielded the highest average percolated water volume, which influenced the total mass values greatly. The only similar trend shared by the soil water results from the June and July simulation series is that the NT treatment had a significantly greater percolated water volume than the other treatments.

Overall Lysimeter Nutrient Results

The overall results from the lysimeter nutrient collection from the June and July simulation series showed that the no-till treatment yielded 28 percent less NH_3 total mass compared to conventional tillage (Table 4.13). Strip tillage resulted in 19 percent less NH_3 total mass compared to the CT treatment. The ST treatment yielded the greatest TKN total mass in percolated water. The negative percent reductions shown in Table 4.13 show that the no-till treatment had the most NO_3^-, TN, PO_4^{3-}, and TP mass in soil water. The NT treatment, however, had 838 L (53.0 mm) more total percolated water volume than ST and 1420 L (90.0 mm) more than CT.

Table 4.13 The overall soil water results for the June and July simulation series

Tillage Treatments	Total Perc Water (mm)	Total Mass per area in Percolated Water: NO_3^- (mg ha^{-1})	NH_3 (mg ha^{-1})	TKN (mg ha^{-1})	TN (mg ha^{-1})	PO_4^{3-} (mg ha^{-1})	TP (mg ha^{-1})
CT	54	57	10	23	80	3.34	1.36
	Percent less than CT						
ST	-68	-152	19	-39	-120	-62	-166
NT	-167	-276	28	-3	-198	-189	-204

4.1.4.2 Pesticides in Percolated Water

One composite lysimeter sample per tillage treatment from each simulation series was tested for the pesticides chlorpyrifos and flumetralin. There was not sufficient data to conduct statistical analysis. The results from the June and July simulation series are shown in Table 4.14.

Table 4.14. The concentration and mass values of pesticides in the soil water

		Lysimeter Results				
		Concentration in Soil Water			Mass in Soil Water	
Rainfall Simulation	Tillage Treatments	**Chlorpyrifos** (µg L^{-1})	**Flumetralin** (µg L^{-1})	**Percolated Volume** (L)	**Chlorpyrifos** (µg)	**Flumetralin** (µg)
June	**CT**	0.00935	0.523	118.3	1.11	61.91
	ST	0.0278	0.0205	134.4	3.73	2.75
	NT	0.0190	0.0245	238.7	4.53	5.86
July	**CT**	--*	0.0156	165.7	--	2.59
	ST	--	--	343.5	--	--
	NT	0.00620	--	518.6	3.22	--

* Not detected, the pesticide was not present or present below the detection limit of 0.3 µg L^{-1}.

June Pesticide Results

The June series results show that the ST treatment had the greatest chlorpyrifos concentration in soil water, followed by NT, and CT had the least. The no-till treatment had the greatest total mass of chlorpyrifos in the soil water, followed by ST, and CT had the least. The greater percolated water volume from the NT treatment influenced the chlorpyrifos mass results considerably. The conventional tillage treatment had the greatest concentration and total mass of flumetralin in the soil water in June, followed by NT then ST. The environment of the conservation tillage treatments in the soil profile may have allowed flumetralin to decay at a greater rate than the CT treatment environment. The amount of pesticide lost per tillage treatment accounted for less than 1% of the quantities applied.

July Pesticide Results

Even though there were more lysimeter samples collected after the July simulation series, pesticide was only detected in two composites. Chlorpyrifos was observed from NT and flumetralin was observed from CT. The greater volume of percolated water from the July series may have diluted the pesticide below the detection limit (0.3 $\mu g\ L^{-1}$). The amount of pesticide lost per tillage treatment accounted for less than 1% of the quantities applied.

4.2 GLEAMS Model Simulation Results

The second objective of this study was to perform a long-term simulation with GLEAMS to evaluate the relative effectiveness of three levels of tillage in minimizing edge-of-field losses of sediment, nutrients, and pesticides. The GLEAMS model inputs were estimated using soil parameters from the Speedwell sandy loam soil data and typical tobacco production operations similar to those encountered in the field experiment portion of this study. Precipitation inputs for the 50-year simulation, 50 years of daily precipitation values, were developed using the weather generator software CLIGEN.

The 50-year CLIGEN weather generated data created an average of 1,123 mm (44.2 in.) of rainfall. Based on a 50-year GLEAMS simulation there was a 29 and 32 percent reduction in average annual runoff depth when comparing strip tillage (ST) and no-till (NT) to conventional tillage (CT) (Table 4.15). Crop residue present on the soil surface in the conservation tillage practices likely reduced runoff volume from large storm events and may have eliminated runoff from smaller events. A reduction in runoff results in an increase in soil moisture and increased potential for percolation below the active rootzone. Compared to the CT practice, there was a 16 percent and 18 percent increase in percolated water from ST and NT practices, respectively.

Table 4.15. Average annual runoff and percolated water depth simulated by GLEAMS

Tillage Practice	Rainfall		Runoff		Percolation below root zone	
	mm	in	mm	in	mm	in
CT	1123	44.2	152	5.99	258	10.2
ST	1123	44.2	109	4.28	308	12.1
NT	1123	44.2	103	4.07	314	12.4

4.2.1 Recurrence Intervals

Recurrence intervals for runoff, percolation, sediment, nutrients and pesticide mass losses were compared for three levels of tillage, conventional tillage, strip tillage, and no-till. The GLEAMS results for runoff depth are shown in Figure 4.3. For a 5-year recurrence interval storm, strip tillage and no-till reduced runoff volume by, 27 and 31 percent, respectively when compared to conventional tillage (Figure 4.3). For the 51-year recurrence interval storm, strip tillage reduced runoff by 27 percent and no-till reduced runoff by 34 percent compared to conventional tillage. The CT practice consistently yielded greater runoff volume than the conservation tillage practices. This result is mainly due to the difference in the runoff curve number between the simulated tillage practices.

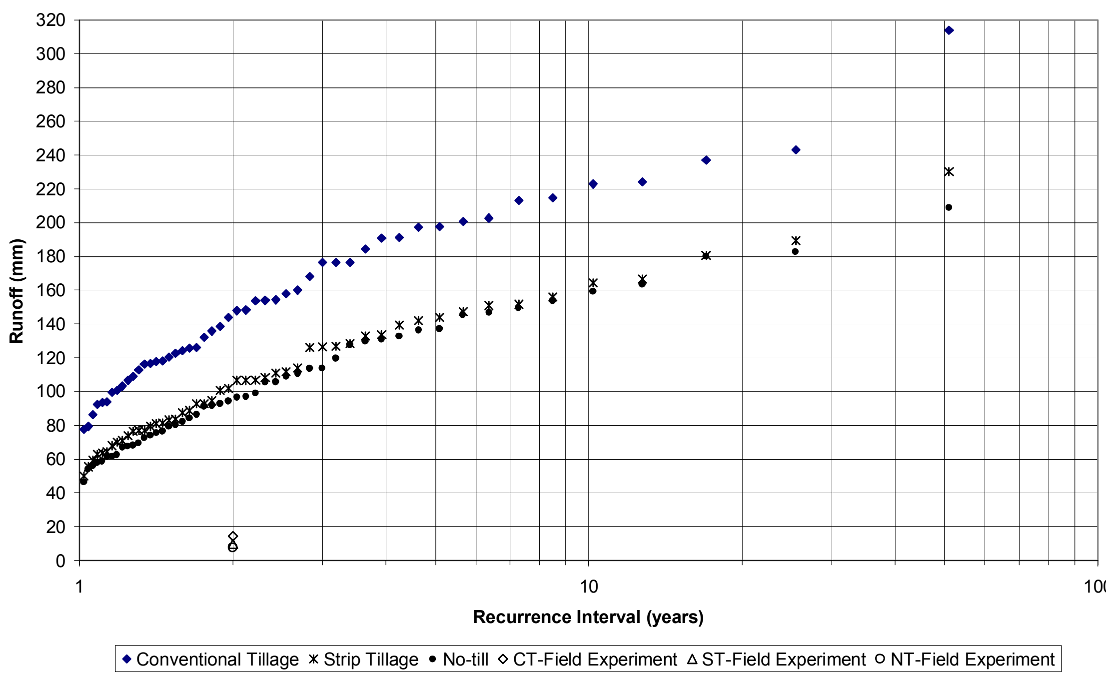


Figure 4.3 Recurrence intervals of runoff volume from conventional tillage, strip tillage, and no-till

The 2-year recurrence interval field experiment rainfall simulations were June Run1, Run2 and Run3 and July Run2 and Run3. The runoff depth results from these simulations were averaged and plotted on Figure 4.3 with the uncalibrated GLEAMS runoff depth results. A comparison with the GLEAMS values as the basis shows that the field experiment runoff depth results were 90 to 92 percent lower than the GLEAMS calculations for the same 2-year recurrence interval.

Examining the simulation results shown in Figure 4.4 for a 5-year recurrence interval storm, strip tillage and no-till reduced TSS mass lost in runoff by, 59 and 67 percent, respectively compared to conventional tillage. The strip tillage and no-till practices reduced TSS mass lost in runoff by, 59 and 64 percent, respectively compared to conventional tillage for a 51-year recurrence interval storm. The CT practice had four tillage operations throughout the rotation of tobacco and rye winter cover. These operations loosened the soil and made it more susceptible to erosion. The conservation tillage practices, with reduced or no tillage preformed and residue cover present, protected the soil from detachment by raindrop impact and subsequent movement and delivery by runoff water.

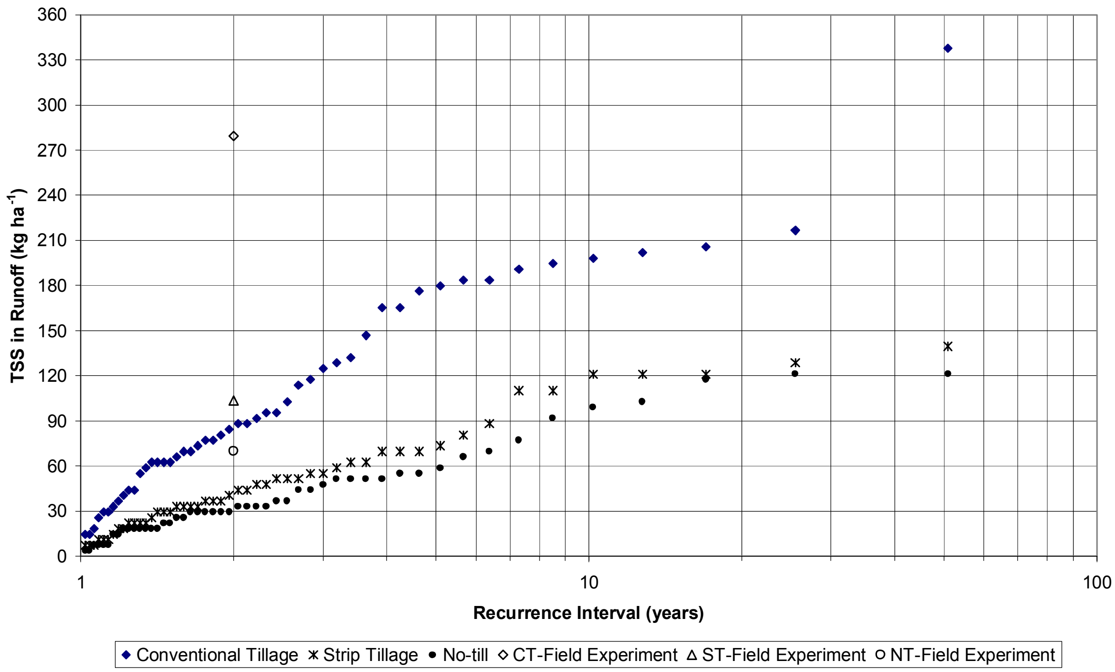


Figure 4.4 Recurrence intervals of TSS from conventional tillage, strip tillage, and no-till

The 2-year recurrence interval field experiment rainfall simulations were June Run1, Run2 and Run3 and July Run2 and Run3 based on rainfall intensity. The TSS mass loss results from these simulations were averaged and plotted on Figure 4.4 with the uncalibrated GLEAMS runoff depth results. A comparison with the GLEAMS values as the basis shows that the field experiment runoff depth results were -217 to -111 percent lower than the GLEAMS calculations for the same 2-year recurrence interval. The negative percent reductions indicate that the field experiment TSS results were greater than the GLEAMS calculations for the 2-year recurrence interval for all tillage practices.

It is important to note the differences between constituent losses generated from both frequent and less frequent rainfall events to evaluate the ability of conservation tillage BMPs to reduce the losses from both less frequent more extreme events and more frequent less extreme storm events. The simulated annual loss for each year was plotted in ascending rank order as a percentage of the cumulative 50-year loss (Figure 4.5). By ranking annual losses in this way, it was discovered that only a few (approximately 25%) years contributed to more than 50% of the cumulative 50-year loss. For conventional tillage, the greatest TSS mass in runoff value was 6.5 percent of the 50-year total mass loss. During the year this occurred, 95 percent of the TSS lost was due to a 5.44 inch (138.2 mm) July rain that produced 2.13 inches (54.1 mm) of runoff. This storm was the first rainfall event that generated soil loss from the field and was 29 days after the last cultivation of the conventional tillage practice.

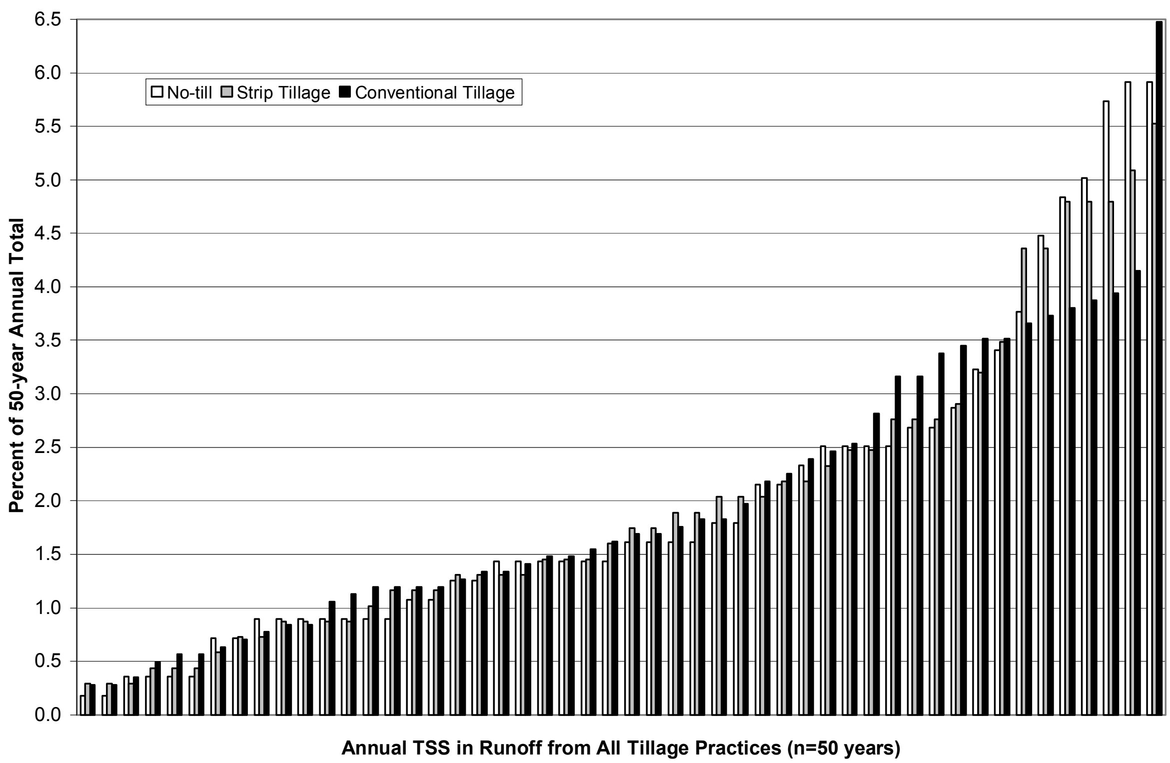


Figure 4.5 Ranked plot of simulated annual TSS mass loss as a percent of cumulative 50-year loss, conventional tillage

The greatest TSS loss in percent of the 50-year total mass lost from strip tillage and no-till were 5.5 and 5.9 percent, respectively (Figure 4.5). During the year that strip tillage produced the most TSS loss, 24 percent of the TSS lost was due to a 2.6 inch (66.0 mm) September rain that produced 0.48 inches (12.2 mm) of runoff. This September rainfall event was the first to generate soil loss after the last cultivation of the field in July. During the year that no-till produced the most TSS loss, 61 percent of the TSS lost was due to a 1.3 inch (33.0 mm) December rain that produced 0.80 inches (20.3 mm) of runoff.

For a 5-year recurrence interval, strip tillage and no-till reduced nitrogen in runoff by, 30 and 48 percent, respectively compared to conventional tillage (Figure 4.6). The strip tillage and no-till practices reduced nitrogen lost in runoff by, 30 and 44 percent, respectively compared to conventional tillage for a 51-year recurrence interval storm. A greater runoff volume was simulated from the conventional tillage practice, this may be the source of increased nitrogen in runoff.

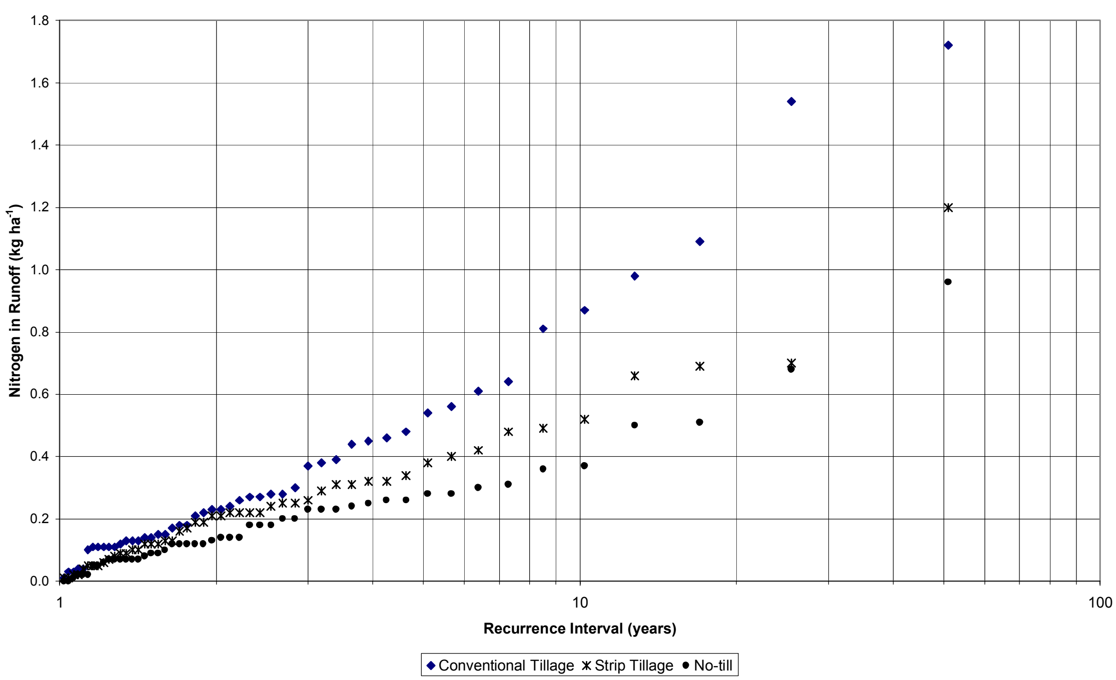


Figure 4.6 Recurrence intervals of nitrogen in runoff from conventional tillage, strip tillage, and no-till

The GLEAMS model did not simulate any ammonia (NH_3) in runoff or percolate water. A study using GLEAMS to simulate nutrients leaching below the soil surface also concluded that GLEAMS did not predict ammonia loadings adequately (Mamillapalli et al., 1994). Very low ammonia levels were observed in the soil water, which GLEAMS predicted as zero mg L^{-1}.

For a 5-year recurrence interval, strip tillage and no-till reduced nitrate leaching past the tobacco root zone (45.7 cm) by, 0.5 and 2.8 percent, respectively compared to conventional tillage (Figure 4.7). The strip tillage and no-till practices lost slightly more nitrate in percolated water, 0.3 and 1.6 percent, respectively, compared to conventional tillage for a 51-year recurrence interval storm. The annual values of nitrate transport by percolated water were similar across the tillage practices.

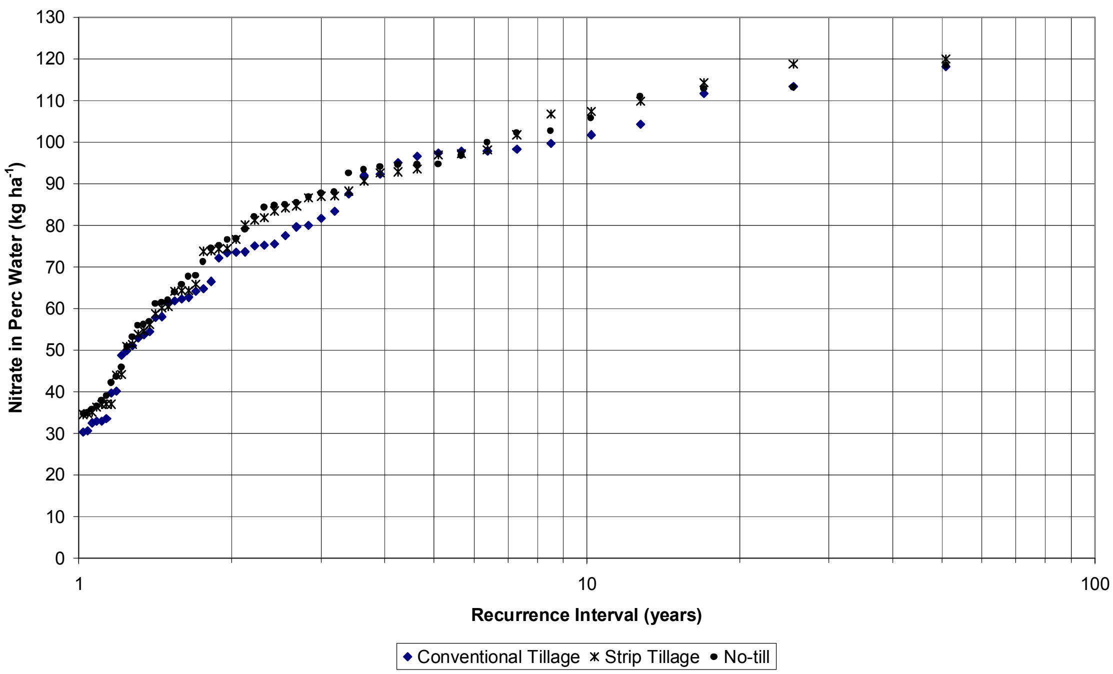


Figure 4.7 Recurrence intervals of nitrogen in percolated water from conventional tillage, strip tillage, and no-till

A study by Bakhsh and Kanwar (2001) showed that the difference between moldboard plow, ridge till and no-till tillage practices did not adequately affect the GLEAMS model simulation results for soil water quality. This is results is also seen here with only small differences between tillage treatments regarding nitrate in subsurface water.

For a 5-year recurrence interval, strip tillage and no-till yielded more phosphorus in runoff than conventional tillage by, 86 and 87 percent, respectively (Figure 4.8). The strip tillage and no-till practices both yielded more phosphorus in runoff by 91 percent compared to conventional tillage for a 51-year recurrence interval storm. The greater mass and concentrations soluble phosphorus from the conservation tillage practices is consistent with the results of the field experiment results where leaching from the residue cover was considered to be the main source of the phosphorus in runoff.

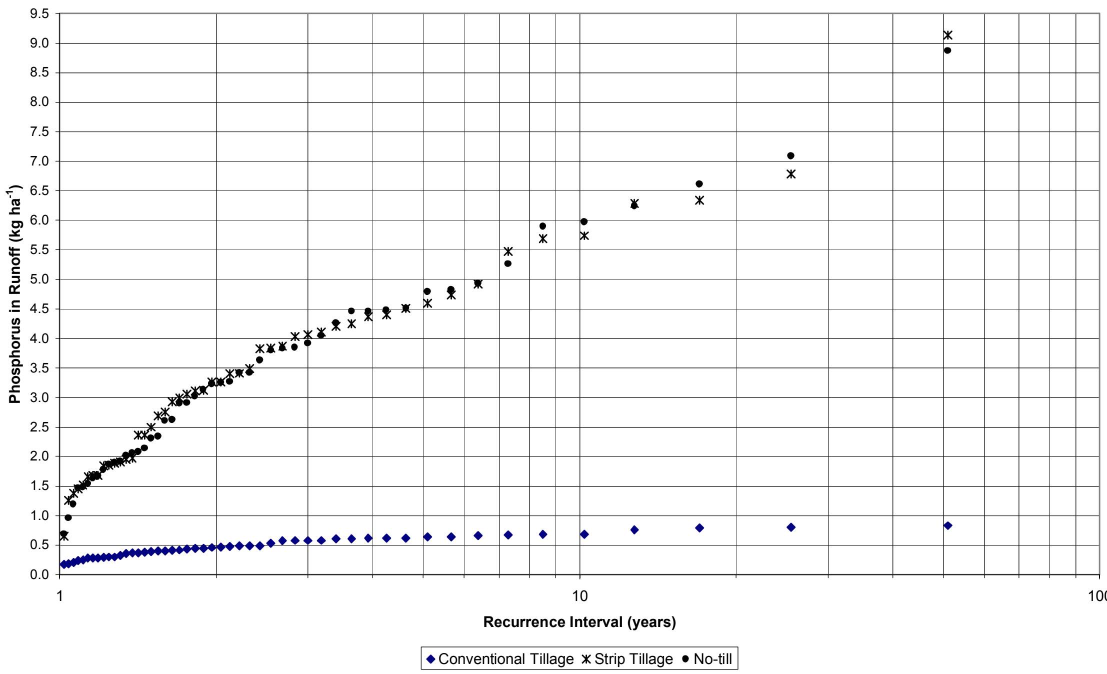


Figure 4.8 Recurrence intervals of phosphorus from conventional tillage, strip tillage, and no-till

A study using the CREAMS model to simulate different tillage practices on cotton showed that the CREAMS model predicted higher phosphorus in runoff from the conservation tillage practice than the conventional tillage practice (Yoon et al., 1991). The CREAMS and GLEAMS model have similar nutrient model components.

GLEAMS output showed that the model predicted that no phosphorus would leach past the root zone of the tobacco, 45.7 cm. The field experiment showed that some soluble phosphorus does reach this depth even in a soil not initially saturated with phosphorus.

For a 5-year recurrence interval, strip tillage and no-till reduced the pesticide chlorpyrifos in runoff by 36 and 57 percent, respectively compared to conventional tillage (Figure 4.9). The strip tillage and no-till practices reduced chlorpyrifos lost in runoff by, 32 and 51 percent, respectively compared to conventional tillage for a 51-year recurrence interval storm. Chlorpyrifos is strongly attracted to soil particles, so these reductions in pesticide loss could be due to a combination of less soil disturbing operations, which reduced the TSS in runoff, along with a lower average annual runoff volume from the conservation tillage practices.

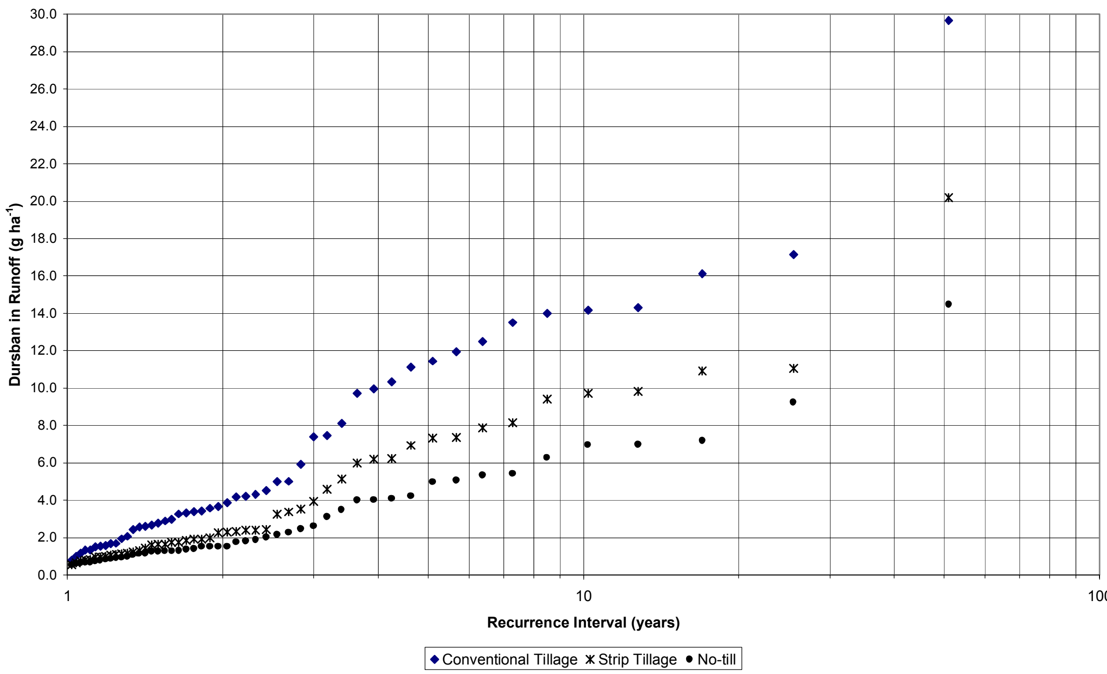


Figure 4.9 Recurrence intervals of chlorpyrifos in runoff from conventional tillage, strip tillage, and no-till

During the year with the most chlorpyrifos loss, a 2.67-inch (67.8 mm) May rain that produced 0.67 inches (17.0 mm) of runoff and caused 81 percent of the chlorpyrifos lost from the conventional tillage practice. This storm occurred two days after the chlorpyrifos was applied to the tobacco field. The timing of this large May rainfall event is the reason the storm had a major impact on the annual loss for that year. During the year with the most chlorpyrifos loss from the strip tillage practice, 86 percent of the annual total chlorpyrifos was lost during the same May rainfall event, which produced

0.52 inches (13.1 mm) of runoff. The same May rainfall event caused 90 percent of the chlorpyrifos loss from the no-till practice during the year with the most total chlorpyrifos loss. The conservation tillage practices did not have tillage on the day of this May rainfall event. The percentage of the total loss was greater from the conservation tillage practices because the pesticide was not incorporated into the soil matrix and was more easily carried off the surface with runoff.

For a 5-year recurrence interval, strip tillage and no-till reduced the pesticide flumetralin in runoff by, 31 and 38 percent, respectively compared to conventional tillage (Figure 4.10). The strip tillage and no-till practices reduced flumetralin lost in runoff by, 24 and 36 percent, respectively compared to conventional tillage for a 51-year recurrence interval storm. The reductions in flumetralin loss could also be due to a combination of less soil disturbing operations along with a lower average annual runoff volume from the conservation tillage practices.

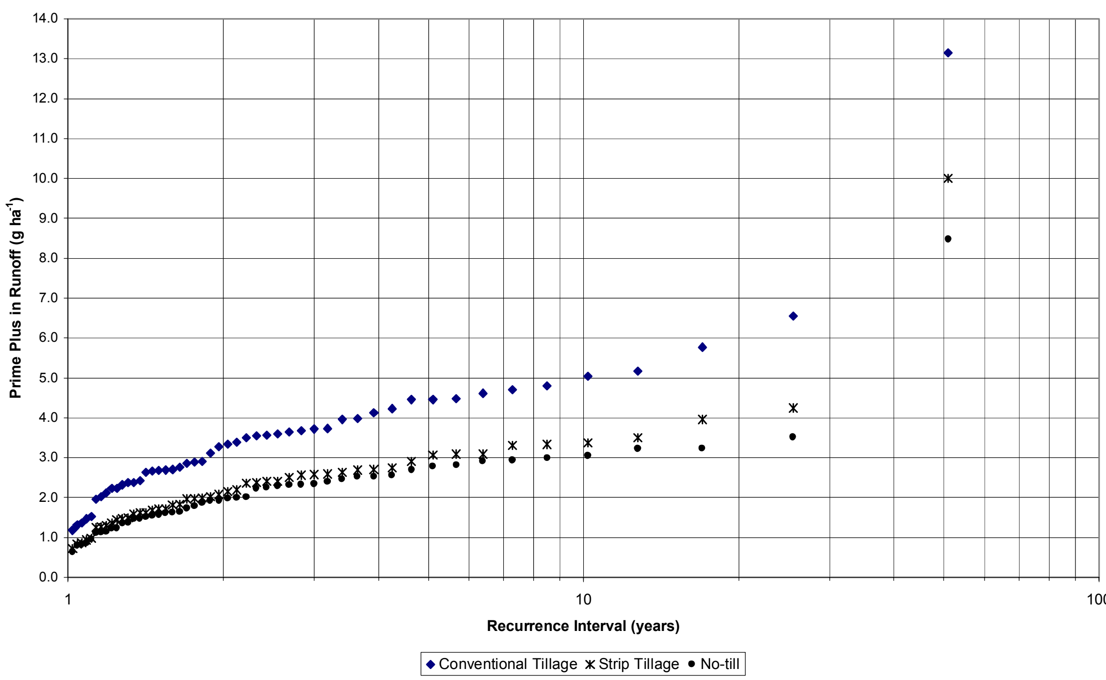


Figure 4.10 Recurrence intervals of flumetralin in runoff from conventional tillage, strip tillage, and no-till

During the year with the most flumetralin loss, a 5.44-inch (138.2 mm) July rain caused 86 percent of the flumetralin lost from the conventional tillage practice. This storm occurred two days after the flumetralin was surface applied to the tobacco field.

The same July rainfall event generated the most flumetralin loss, 89 percent, for the strip tillage practice during the year with the most flumetralin loss. The no-till practice lost 87 percent of the annual total flumetralin mass from the same July rainfall event. The percentages of flumetralin lost from each tillage practice were similar because none of the simulated practices incorporated flumetralin after it was applied and the same rainfall event had the greatest effect on the top year of the 50-year total loss.

4.2.2 Overall GLEAMS Results

4.2.2.1 Average Annual Results

The average annual results show that the conservation tillage practices reduced runoff volume, sediment, and nitrogen, chlorpyrifos and flumetralin in runoff, compared to the CT practice (Table 4.16). Over 50 years, these reductions would be important to the surrounding water bodies, wildlife, and the production of the field. GLEAMS simulated that the ST and NT practices would yield more percolated water. The negative reductions show that the conservation tillage practices contributed more phosphorus in runoff than the CT practice. This can be partly attributed to the simulation of leaching of cover crop phosphorus into the runoff water by GLEAMS. The annual averages of nitrate in percolated water were very similar across the tillage practices.

Table 4.16 The average annual values of constituents from CT and the percent reductions from the conservation tillage practices

	Conventional Tilllage Annual Averages							
Tillage Practice	**Runoff Depth** mm	**Percolated Water** mm	**TSS in Runoff** kg ha^{-1}	**Nitrogen in Runoff** kg ha^{-1}	**Phosphorus in Runoff** kg ha^{-1}	**Chlorpyrifos in Runoff** g ha^{-1}	**Flumetralin in Runoff** g ha^{-1}	**Nitrate Leached** kg ha^{-1}
CT	152	258	104	0.35	0.48	6.26	3.47	71
	Percent less than CT							
ST	29	-19	52	30	-622	37	33	-4
NT	32	-22	61	47	-614	55	39	-5

4.2.2.2 GLEAMS and Field Experiment Comparisons

It is possible to make relative comparisons between the model results and the field experiment results if one recalls that the GLEAMS results are average annual values or annual totals and the field experiment results are averages or totals from only six rainfall simulations. GLEAMS simulated more runoff, sediment, nitrogen in runoff, chlorpyrifos and flumetralin from the conventional tillage practice than the ST and NT practices. The field experiment results showed these same trends. The field experiment also showed, however, that the CT treatment yielded higher phosphorus in runoff than the conservation tillage treatments. GLEAMS simulated slightly more nitrate in percolated water and considerable more phosphorus in runoff from the strip tillage and no-till practices. The field experiment results showed only slight differences between the tillage treatments regarding nitrate detected in the soil water. It is reasonable that GLEAMS predicted that the nitrogen in the percolated water did not differ considerably between tillage practices. The field experiment results did not show the same trend as GLEAMS regarding the phosphorus in runoff. The CT treatment yielded the most phosphorus mass in runoff from the field experiment. GLEAMS greatly under predicted phosphorus, chlorpyrifos and flumetralin in percolated water. Flumetralin in percolated water was simulated from only the first 3 years by GLEAMS; no chlorpyrifos in percolated water was simulated. The field experiment showed pesticides and phosphorus in the percolated water samples after both simulation series.

The June Run1 and July Run2 rainfall simulations were included in the GLEAMS daily precipitation data to make general comparisons between the GLEAMS simulated results and the field experiment results (Table 4.17).

Table 4.17 Event comparison of GLEAMS results and the field experiment results

Series	Tillage Practice	Runoff mm	TN kg ha^{-1}	TP kg ha^{-1}	TSS kg ha^{-1}	Chlorpyrifos g ha^{-1}	Flumetralin g ha^{-1}
June Run1 Field Experiment	**CT**	8.5	1.00	0.42	201	0.081	0.0021
	ST	4.5	0.31	0.11	50.2	0.013	0.0015
	NT	6.0	0.69	0.23	82.2	0.021	0.00025
GLEAMS	**CT**	0.76	0.02	0.01	0	0.095	0.0005
	ST	0.25	0	0.02	0	0.089	0.0005
	NT	0	0	0	0	0	0
July Run1 Field Experiment	**CT**	17.6	1.73	0.62	332	0.0385	0
	ST	10.6	0.88	0.23	134.0	0.0085	0
	NT	7.2	0.58	0.13	64.4	0.0051	0
GLEAMS	**CT**	1.02	0	0.01	0	0.052	0.0003
	ST	0.25	0	0.02	0	0.049	0.0003
	NT	0	0	0	0	0.049	0.0003

For the June Run1 storm, the ST and NT yielded 48 and 29 percent less runoff than the CT treatment, respectively. GLEAMS simulated the same trend as 67 percent less runoff from ST compared to the CT practice, and no runoff from the no-till practice. The GLEAMS runoff values were lower than the field experiment results by one order of magnitude. The GLEAMS results show that no sediment was lost in runoff from any tillage practice. The field results show 201, 50 and 82 kg ha^{-1} TSS lost from the CT, ST and NT treatments, respectively. The GLEAMS results show that no sediment was lost in runoff from any tillage practice, a significant under prediction.

The GLEAMS results show a minute amount of nitrogen mass in runoff from the CT practice and no nitrogen mass from the conservation tillage practices. In reality, all tillage treatments yielded nitrogen mass in runoff from the June Run1 storm. The nitrogen in runoff GLEAMS result for the CT practice was an order of magnitude less than the field experiment results. The GLEAMS output shows small amounts of phosphorus mass in runoff from the CT and ST practices and no phosphorus mass in runoff from the NT practice. The field experiment results showed that phosphorus was present in the runoff from all tillage treatments and the results for the CT and ST treatments were one order of magnitude greater than the GLEAMS results.

Small amounts of chlorpyrifos mass were detected in the June Run1 field experiment results for all tillage treatments. The trend shown in the GLEAMS results did not match the trend in the field experiment results. GLEAMS did not simulate any chlorpyrifos mass for the NT practice. Flumetralin was detected from all tillage practices from the field experiment results, but only simulated from the CT and ST practices by GLEAMS. No flumetralin was simulated from the NT practice by GLEAMS, however, the amount detected from the field experiment was very small, 0.0002 g ha^{-1}.

The relative differences between GLEAMS results and the field experiment results from the July Run1 rainfall event were also observed. GLEAMS under predicted the amount of runoff from all tillage practices and predicted that no runoff occurred from the NT practice. However, the runoff trends were the same between the simulated and observed storms, CT was greater than ST, which was greater than NT. GLEAMS also predicted that no sediment was lost from any tillage practice from the July Run1 storm. Another significant under prediction as the field experiment results show that 332, 134, and 64 kg ha^{-1}, was lost from the CT, ST, and NT treatments, respectively.

GLEAMS simulated no nitrogen mass loss in runoff from all tillage practices from the July Run1 storm (Table 4.17). The field experiment results show that nitrogen was detected in runoff from this rainfall event. Phosphorus in runoff was also under predicted by GLEAMS. GLEAMS predicted that no phosphorus loss occurred from the NT practice when the field experiment results show 0.13 kg ha^{-1} were detected. The trend developed by GLEAMS did not match the trend observed during the field experiment.

GLEAMS over predicted chlorpyrifos mass in runoff from July Run1 from the CT, ST, and NT treatments, respectively. Both simulated and observed trends showed that the CT practice yielded more chlorpyrifos than the conservation tillage practices. GLEAMS over predicted the flumetralin mass in runoff from all tillage practices from July Run1. No flumetralin was detected in the results from the field experiment, however GLEAMS predicted 0.0003 g ha^{-1} for all tillage practices.

Values from observed percolated water samples and GLEAMS results were not compared. This was because the field experiment tested percolated water from all three runs of each simulation series after two to four days and the GLEAMS model cannot simulate this situation.

Chapter 5 Summary and Conclusions

5.1 Field Experiment

The impacts of conservation tillage on nutrient, sediment, and pesticide edge-of-field losses and deep percolation losses were studied on a Virginia burley tobacco field. A total of 174 mm of rainfall was simulated on the field plots research area. Total runoff from conventional tillage was 93.6 mm (1478 L). The strip tillage treatment yielded 33 percent less runoff, and the no-till treatment yielded 50 percent less runoff than conventional tillage.

The treatments were statistically different regarding the runoff volume for the June Run3, and all July runs. In these runs the CT treatment yielded significantly greater runoff volume. The TP and TSS mass in runoff was statistically greater from the CT treatment for June Run3. The treatments were statistically different regarding NO_3^- mass for July Run1, Run2, and Run3. Greater amounts of NO_3^- were lost from the CT treatment. The CT treatment yielded statistically greater amounts of TN mass for July Run1 and PO_4^{3-} mass for July Run3 than the conservation tillage treatments.

The TKN, TP and TSS mass loading trends were the same throughout the July Runs: the conventional tillage treatment was greater than strip tillage, which was greater than the no-till treatment averages. This trend was established in the June simulations with the exception of June Run 1, when the no-till treatment yielded more TKN, TP and TSS than the strip tillage treatment. Trends for NO_3^-, PO_4^{3-}, and NH_3 were the same throughout July: the conventional tillage treatment was greater than strip tillage, which was greater than the no-till treatment averages. The June Run1 simulation may have served as an initial flushing of the plots. As results consistent concentration and mass loss trends developed after the first simulated storm event. The sum of all runoff losses show that there was less total mass of NO_3^-, NH_3, TKN, $PO4^{3-}$, TP, and TSS in runoff from the no-till treatment and strip tillage compared to conventional tillage. The no-till treatment was superior to strip tillage in reducing TSS and all nutrients, except NH_3. The strip tillage and no-till treatments reduced NH_3 by 54 percent and 46 percent, respectively.

The strip tillage treatment yielded 77 percent less, and no-till yielded 82 percent less chlorpyrifos in runoff compared to the conventional tillage treatment. The no-till treatment resulted in 30 percent less flumetralin in runoff than conventional tillage. The strip tillage treatment yielded 6.8 percent more flumetralin than conventional tillage. These simulated rainfall events were not significant in the loss of flumetralin. The amount of chlorpyrifos and flumetralin lost per tillage treatment accounted for less than 1 percent of the quantities applied.

Nutrient, sediment and pesticide losses to deep percolation were measured using porous-cup vacuum lysimeters. A water balance was performed to estimate the total volume of water that percolated past the tobacco root zone per plot per series. This volume was multiplied by the concentrations to give a total mass of pollutant that traveled below the tobacco root zone. The treatments were statistically different regarding the percolated water for both June and July. The NT treatment yielded significantly greater percolated water volume during both simulation series. The TP results for June show that the CT treatment yielded statistically greater TP mass in percolated water compared to the conservation tillage treatments. This statistical difference was not shown from the July simulation series results.

The overall trends from the percolated water results show that the no-till treatment yielded 41 percent less NH_3 and 20 percent less TKN total mass compared to conventional tillage. Strip tillage resulted in 33 percent less NH_3, 7.5 percent less TKN and 39 percent less PO_4^{3-} compared to conventional tillage. No-till had the most NO_3^-, PO_4^{3-}, and TP mass in soil water, however the no-till treatment also had the most percolated water. If nitrate in groundwater is an issue for this area, no-till may not be the best management practice.

The no-till treatment had the greatest total mass of chlorpyrifos lost to deep percolation, followed by strip tillage, and conventional tillage had the least. The conventional tillage treatment had the greatest concentration and total mass of flumetralin lost to deep percolation in June, followed by no-till then strip tillage. Pesticide was only detected in two composites after the July series. Chlorpyrifos was observed from no-till and flumetralin was observed from conventional tillage. The amount of pesticide lost per tillage treatment accounted for less than 1 percent of the quantities applied.

These results show that the no-till farming practice was superior in reducing nutrients, sediment and pesticides in agricultural runoff and percolated water. Strip tillage also reduced the pollutants lost from the field. A combination of reduced tillage and an increase in residue cover limited edge-of-field losses from tobacco production.

5.2 GLEAMS Simulations

The relative effectiveness of conventional tillage, strip tillage and no-till practices in minimizing edge-of-field losses of sediment, nutrients, and pesticides from a tobacco field in Southwest Virginia was accomplished using the GLEAMS model. Input parameters were estimated using Speedwell soil data, typical tobacco production operations and the CLIGEN generated 50 years of daily precipitation values.

The GLEAMS results for annual constituent losses show that conventional tillage generated the greater runoff volume, TSS, nitrogen, chlorpyrifos and flumetralin in runoff than the conservation tillage practices. The conservation tillage practices generated more phosphorus mass in runoff due to leaching of phosphorus from the crop residue biomass. Although the field experiment results showed greater average phosphorus concentration in runoff from the strip tillage and no-till treatments throughout the June and July simulation series, the total mass values were greatest from the conventional tillage treatment.

The major rainfall event contributing to the greatest annual chlorpyrifos loss total for all tillage practices occurred two days after the chlorpyrifos was applied. The timing of this large May rainfall event is the reason the storm had a major impact on the annual loss for that year.

The annual total results from GLEAMS shows the similar overall trends as the field experiment results. The conventional tillage practice was simulated to yield greater runoff volume, TSS, and nitrogen in runoff than the conservation tillage practices. Although the phosphorus in runoff was not consistently greater from the strip tillage and no-till treatments, like GLEAMS suggests, some results show that residue cover leaching may become major sources of soluble phosphorus.

GLEAMS underestimated the phosphorus percolating past the tobacco root zone. The field experiment results show soluble phosphorus was detected in lysimeter samples; however no phosphorus was simulated in water percolating past the first soil horizon.

The conservation tillage practices simulated in GLEAMS were effective in minimizing the loss of agricultural pollutants.

Chapter 6 References

Baker, J. 2003. Personal communication. 29 September and 2 October. Virginia Tech. Blacksburg, VA.

Bakhsh, A., R. S. Kanwar. 2001. Simulating tillage effects on nonpoint source pollution from agricultural lands unsing GLEAMS. *Transactions of ASAE* 44(4): 270-282.

Barisas, S. G., J. L. Baker, H. P. Johnson and J. M. Laflen. 1978. Effect of tillage systems on runoff losses of nutrients, a rainfall simulation study. *Transactions of ASAE* 21: 893-897.

Biggar, J.W. and R.B. Corey. 1969. Agricultural Drainage and Eutrophication. *Eutrophication: Causes, Consequences, Correctives*. International Symposium on Eutrophication, Univ. of Washington. 1:404-409.

Blough, R. F., A. R. Jarrett, J. M. Hamlett, and M. D. Shaw. 1990. Runoff and erosion rater from silt, conventional, and chisel tillage under simulated rainfall. *Transactions of ASAE* 33(5): 1557-1562.

Christensen, L.A., and P. E. Norris. 1983. Tillage systems for reducing soil erosion and water pollution. *Economic Research Service: Agricultural Economic Report* no. 499: 1-27.

Conservation Technology Information Center (CTIC): National Crop Residue Management Surveys. Prepared by Iowa State Univ., Agronomy Department. Conservation tillage practices: practices leaving >30% residue. Available at: http://extension.agron.iastate.edu/soils/PDFs/CTIC/cticus2.pdf. Accessed 3 June 2003.

Cryer, S. A. and P. L. Havens. 1999. Regional sensitivity analysis using a fractional factorial method for the USDA model GLEAMS. *Environmental Modeling and Software*. 14: 613-624.

Dillaha, T. A., B. B. Ross, S. Mostaghimi, C. D. Heatwole, and V. O. Shanholtz. 1988. Rainfall simulation: a tool for best management practice education. *Journal of Soil and Water Conservation* July/Aug: 288-290.

Dow AgroSciences. Chlorpyrifos: The science behind chlorpyrifos. Available at: www.dowagro.com/chlorp/science/fate2.htm. Accessed 19 Nov 2002.

Economic Research Service. United States Department of Agriculture. Updated March 2003. Briefing room: tobacco data tables. Available at: www.ers.usda.gov/briefing/tobacco/background.htm. Accessed 3 June 2003.

Environmental Protection Agency. Office of Pesticide Programs. Chlorpyrifos-Methyl summary. Updated 2000. Available at: www.epa.gov/pesticides/op/chlorpyrifos-methyl/summary.htm. Accessed on 19 Nov 2002.

Freymann, J. 2003. Personal communication regarding unpublished data. 30 September. Virginia: USDA NRCS.

Gish, T. J., A. Shirmohammadi, R. Vyravipillai, and B. J. Wienhold. 1995. Herbicide leaching under tilled and no-tillage fields. *Soil Science Society of America Journal* 59: 895-901.

Groneau, W. S, T. G. Franti, B. L. Benham, and S. D. Comfort. 2001. Reducing long-term atrazine runoff from South Central Nebraska. *Transactions of ASAE.* 44(1): 45-52.

Hawks, S. N. Jr., and W. K. Collins. 1970. Effects of a herbicide and levels of cultivation on yield and value of flue-cured tobacco. *Tobacco Science* 14: 170-172.

Kenimer, A. L., S. Mostaghimi, R. W. Young, T. A. Dillaha, and V. O. Shanholtz. 1987. Effects of residue cover on pesticide looses from conventional and no-tillage systems. *Transactions of ASAE* 30(4): 953-959.

Knisel, W. G., ed. 1980. CREAMS: A field-scale model for chemicals, runoff, and erosion from agricultural management systems, 36-64. Sci. and Educ. Adm., Cons. Res. Report No. 26. USDA.

Knisel, W. G., R. A. Leonard, and F. M. Davis. 1989. Agricultural management alternatives: GLEAMS model simulations. Proceedings of the 1989 Summer Computer Simulation Conference July 24-27, 1989; the Stouffer Austin Hotel; Austin, Texas; edited by Joe K Clema: 701-706.

Knisel, W. G., R. A. Leonard, F. M. Davis, and J. M. Sheridan. 1991. Water balance components in the Georgia coastal plain: a GLEAMS model validation and simulation. *Journal of Soil and Water Conservation*. Nov/Dec: 450-456.

Knisel, W. G., and F. M. Davis. 1999. GLEAMS: Groundwater loading effects of agricultural management systems. Version 3.0, User manual. Pub. No: SEWL-WGK/FMD-050199.

Kross, B.C., A.D. Ayebo, and L.J. Fuortes. 1992. Methemoglobinemia: nitrate toxicity in rural America. *American Family Physician.* 46(1):183-192.

Likens, G. 1972. Eutrophication and aquatic ecosystems. In *Symposium on Nutrients and Eutrophication: the Limiting Nutrient Controversy*, 1:3-14. East Lansing, Mi.

Ma, Q. L., R. D. Wauchope, J. E. Hook, A. W. Johnson, C. C. Truman, C. C. Dowler, G. J. Gascho, J. G. Davis, H. R. Sumner, and L. D. Chandler. 1998. GLEAMS, Opus, and PRZM-2 model predicted versus measured runoff from a coastal plain loamy sand. *Transactions of ASAE* 41(1): 77-88.

Malone, R. W., R. C. Warner, S. R. Workman, and M. E. Byers. 1999. Modeling surface and subsurface pesticide transport under three field conditions using PRZM-3 and GLEAMS. *Transactions of ASAE* 42(5): 1275-1287.

Mamillapalli, S., B. A. Engel, and E. J. Kladivko. 1994. Validation of GLEAMS nutrient component for Midwestern conditions. *Proceeding of the ASAE*. Paper no. 94-2090.

Methods for chemical analysis of water and waste. March 1983. EPA – 600/4-79-020.

Miller, M. H., E. G. Beauchamp, and J. D. Lauzon. 1994. Leaching of nitrogen and phosphorus from the biomass of three cover crop species. *Journal of Environmental Quality* 23: 267-272.

Mostaghimi, S., T. A. Dillaha, and V. O. Shanholtz. 1988. Influence of tillage systems and residue levels on runoff, sediment, and phosphorus losses. *Transactions of ASAE*. 31(1): 128-132.

Richardson, C. W. and A. D. Nicks. 1990. Weather generator description. In: EPIC-erosion/productivity impact calculator: Model documentation. USDA. Technical Bulletin no. 1768.

Shanholtz, V. O., and J. H. Lillard. January 1974. Rainfall intensity – duration – frequency data for selected stations in Virginia. Department of Agricultural Engineering, Research Division, Virginia Polytechnic Institute and State University. Research Division Report 155.

Shelby, P.P. Jr., and D. J. Fowlkes. 1989. A survey of flumetraling carryover in Tennessee. *Tennessee Farm and Home Science*. Winter 149: 20-23.

Shelby, P.P. Jr., W. A. Krueger, G. N. Rhodes, Jr., and D. L. Coffey. 1990. Flumetralin usage in burley tobacco production. *Tobacco International* 192 (15): 20-23.

Shelton, D. P., R. Kanable, and P. J. Jasa. 1997. Estimating percent residue cover using the line-transect method. Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln. Available at: www.ianr.unl.edu/pubs/fieldcrops/g1133.htm. Accessed 9 May 2003.

Smith, M. C., A. B. Bottcher, K. L. Campbell, and D. L. Thomas. 1991. Field testing and comparison of the PRZM and GLEAMS models. *Transactions of ASAE* 34(3): 838-847.

Soil Conservation Society (SCS). 1948. Survey of Smyth County, Virginia.

Stein, O. R., W. H. Neibling, T. J. Logan, and W. C. Moldenhauer. 1986. Runoff and soil loss as influenced by tillage and residue cover. *Soil Science Society of America Journal* 50: 1527-1531.

U.S. EPA. (U.S. Environmental Protection Agency). 1974. National Primary Drinking Water Regulations: Consumer Fact Sheet. Nitrates/Nitrites. http://www.epa.gov/safewater/dwh/c-ioc/nitrates.html. Available: June 13, 2003.

US EPA. 1982. Water quality assessment: A screening procedure for toxic and conventional pollutants-Part 1. Environmental Protection Agency (EPA) paper no. 600-6 82-004a. Environmental Research Laboratory, Athens, Georgia.

Virginia Department of Health. Division of Health Hazards Control. Prime Plus. Available at: www.vdh.state.va.us/HHControl/Prime.pdf. Accessed 19 Nov 2002.

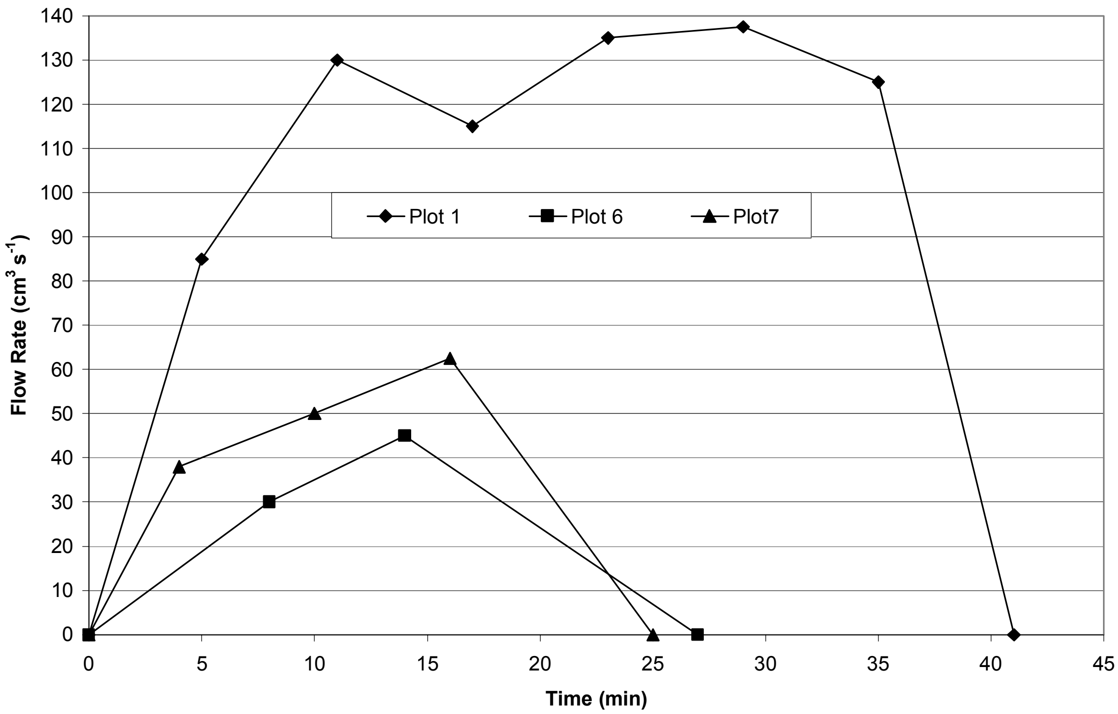
Watts, Randall R. Ed. 1980. Manual of Analytical Methods for the Analysis of Pesticides in Human and Environmental Samples: The sampling and analysis of water for pesticides. Section 10 A, pp. 1-26 and section 10 B, pp. 1-6. EPA-600/8-80-038.

Wood, S. D., and A. D. Worsham. 1986. Reducing soil erosion in tobacco fields with no-tillage transplanting. *Journal of Soil and Water Conservation* May/June: 193-196.

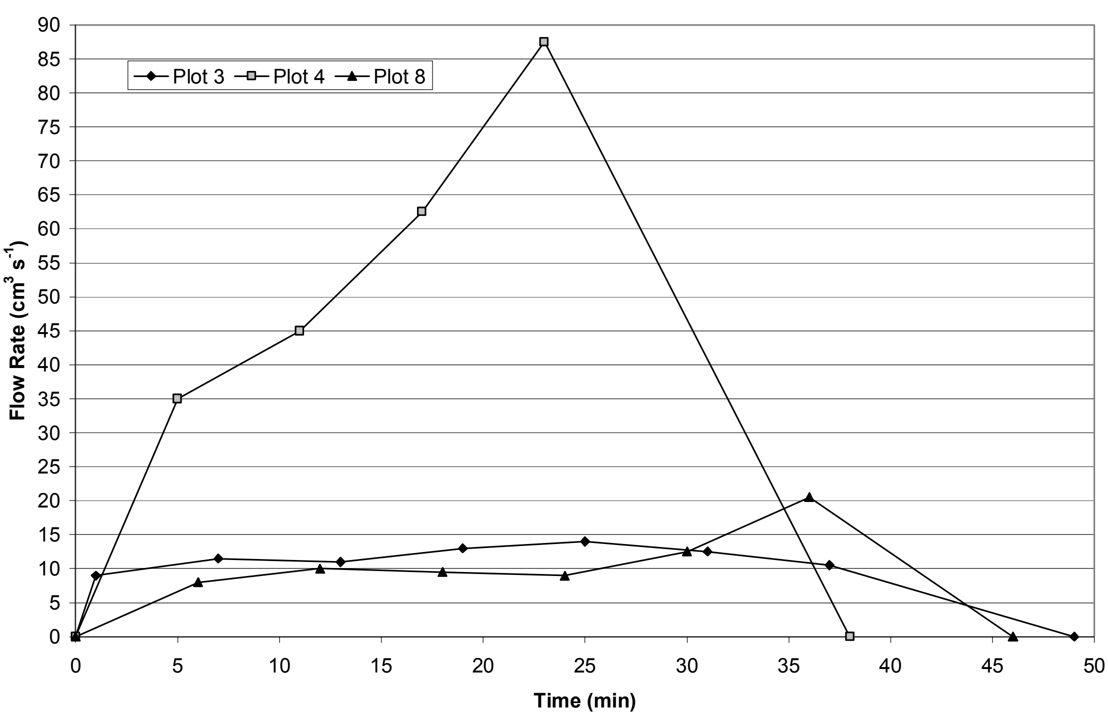
Yoon, K. S., K. H. Yoo, J. M. Soileau, and J. T. Touchton. 1991. Application of the CREAMS model to two tillage systems of cotton. *Proceedings of the ASAE*. Paper no. 912512.

Zacharias S., C. D. Heatwole. 1994. Evaluation of GLEAMS and PRZM for predicting pesticide leaching under field conditions. *Transactions of ASAE.* 37(2): 439-451.

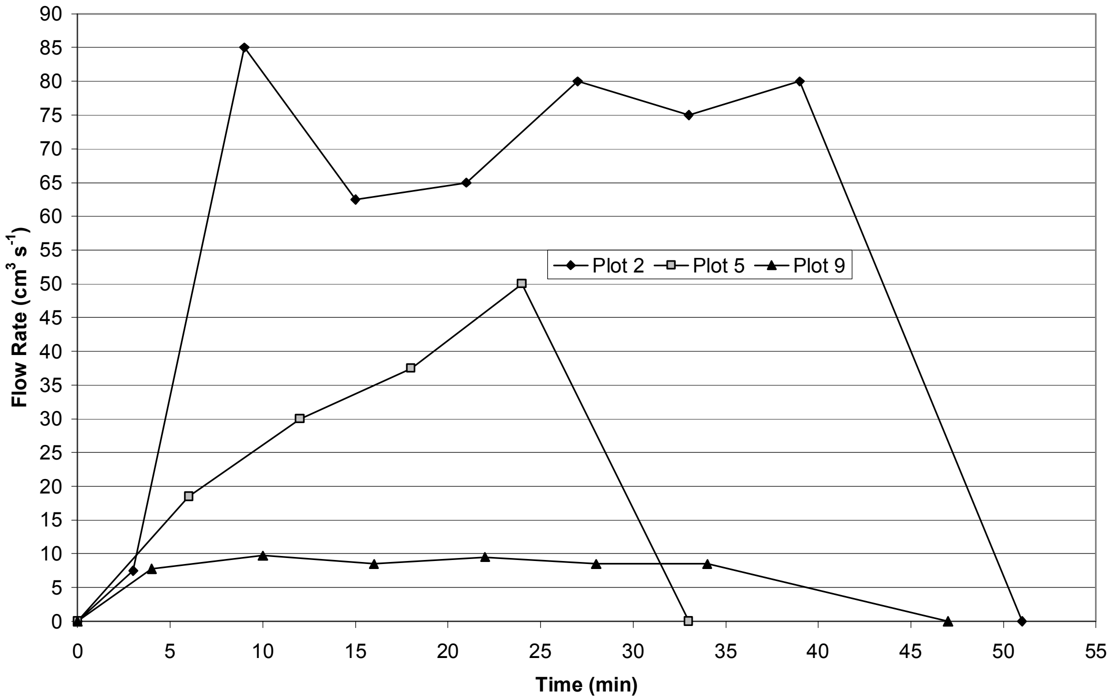
Appendix A
Field Experiment Hydrographs



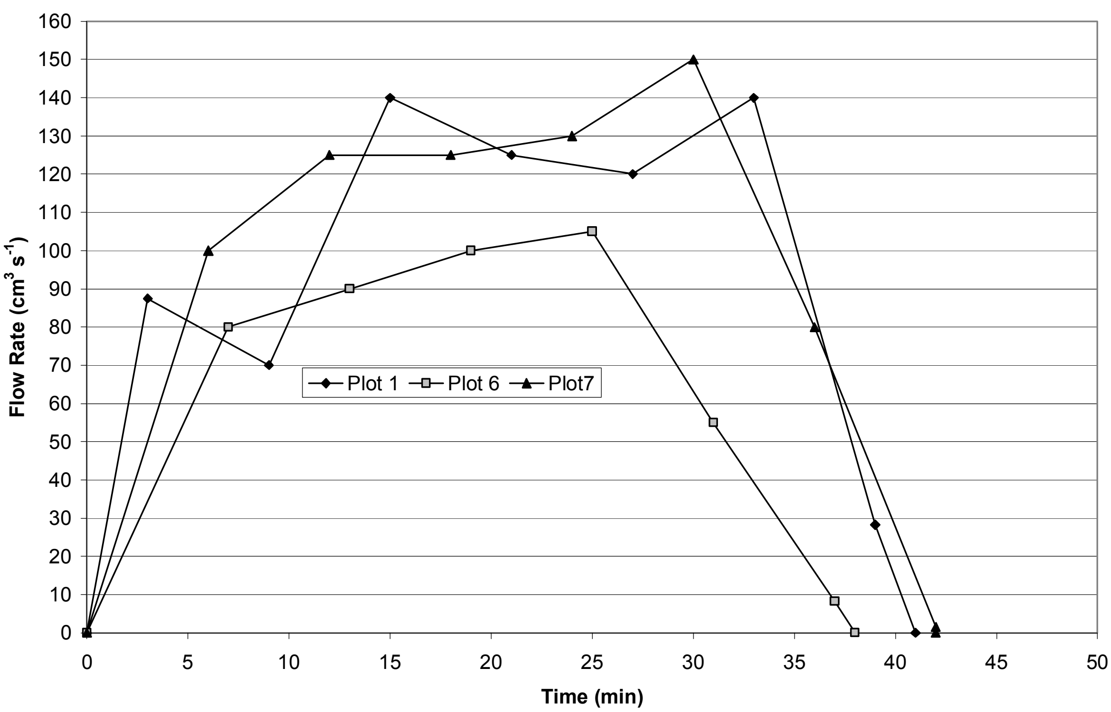
The June Run1 hydrographs for the conventional tillage plots



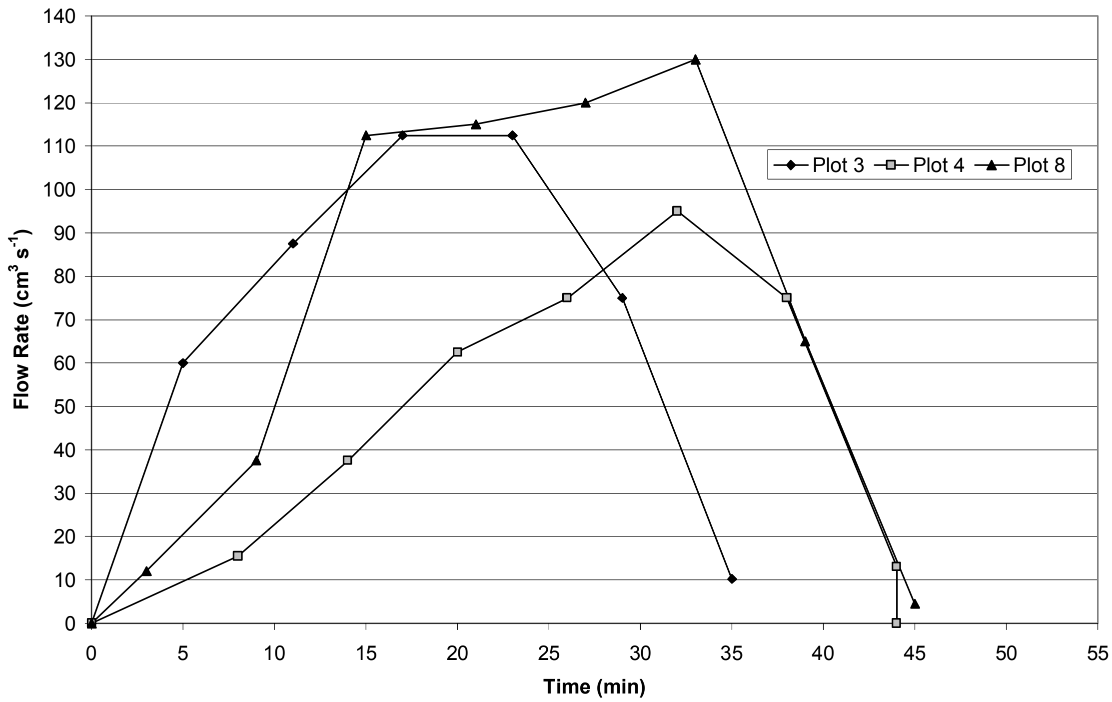
The June Run1 hydrographs for the strip tillage plots



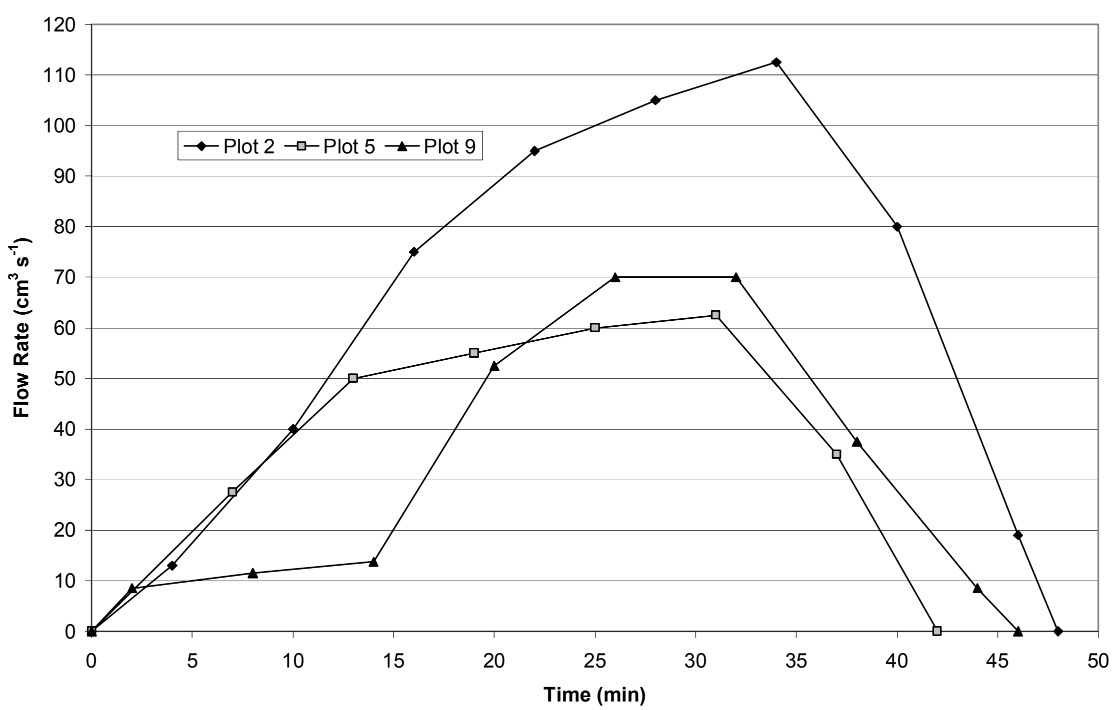
The June Run1 hydrographs for the no-till plots



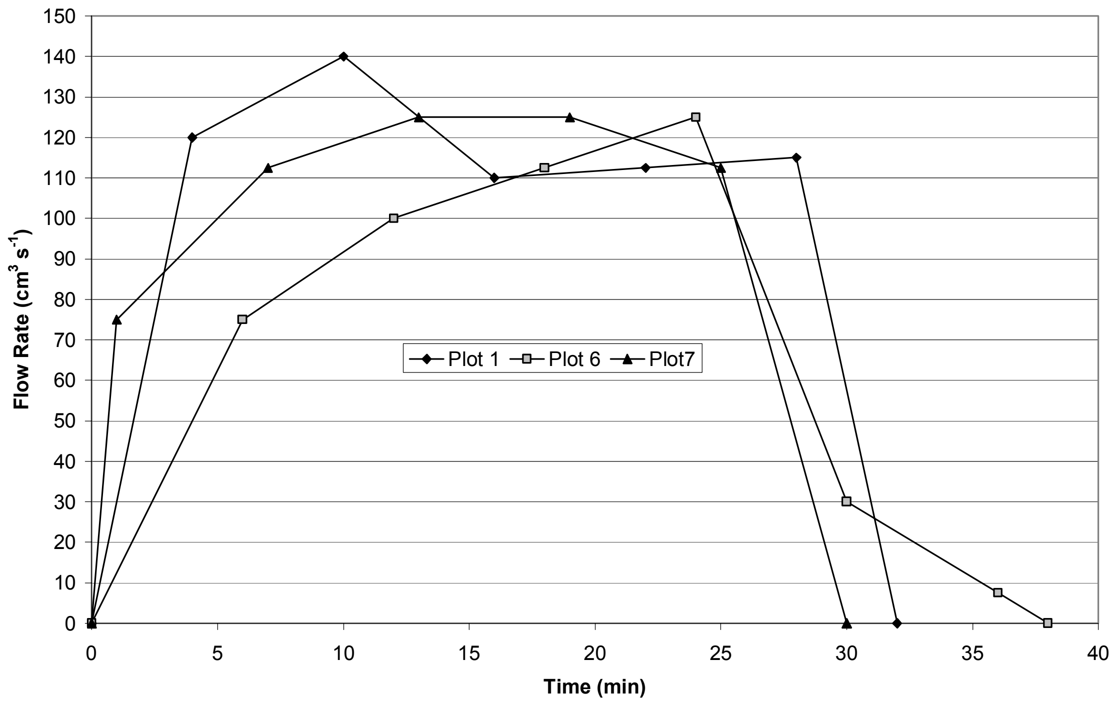
The June Run2 hydrographs for the conventional tillage plots



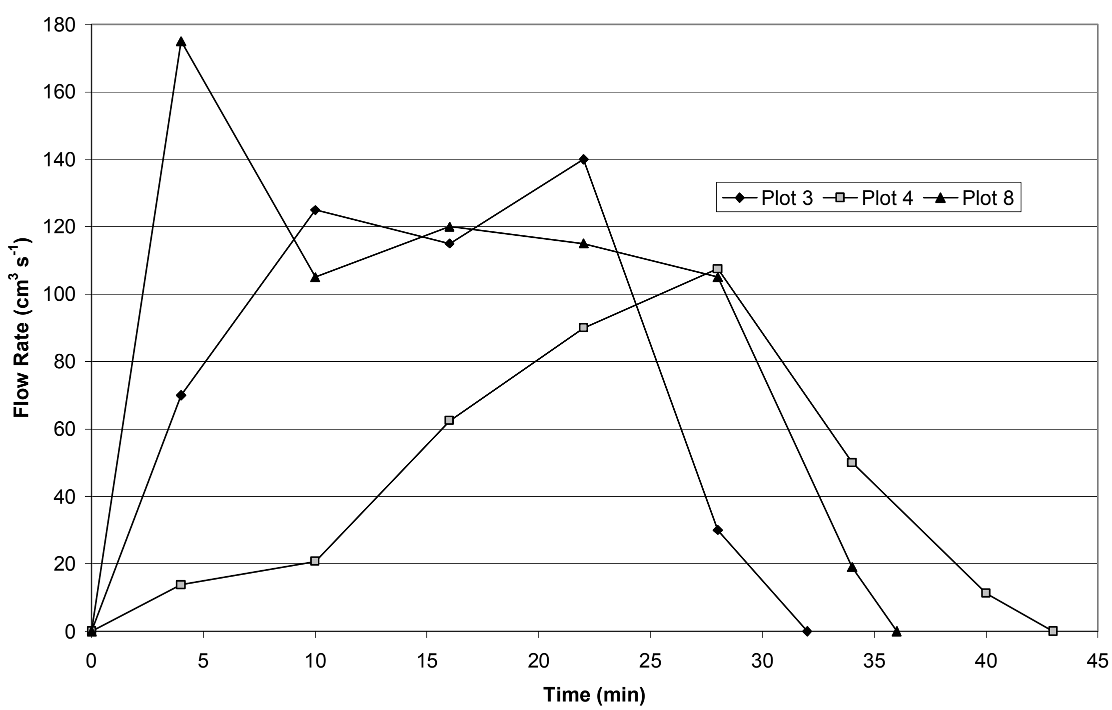
The June Run2 hydrographs for the strip tillage plots



The June Run2 hydrographs for the no-till plots



The June Run3 hydrographs for the conventional tillage plots



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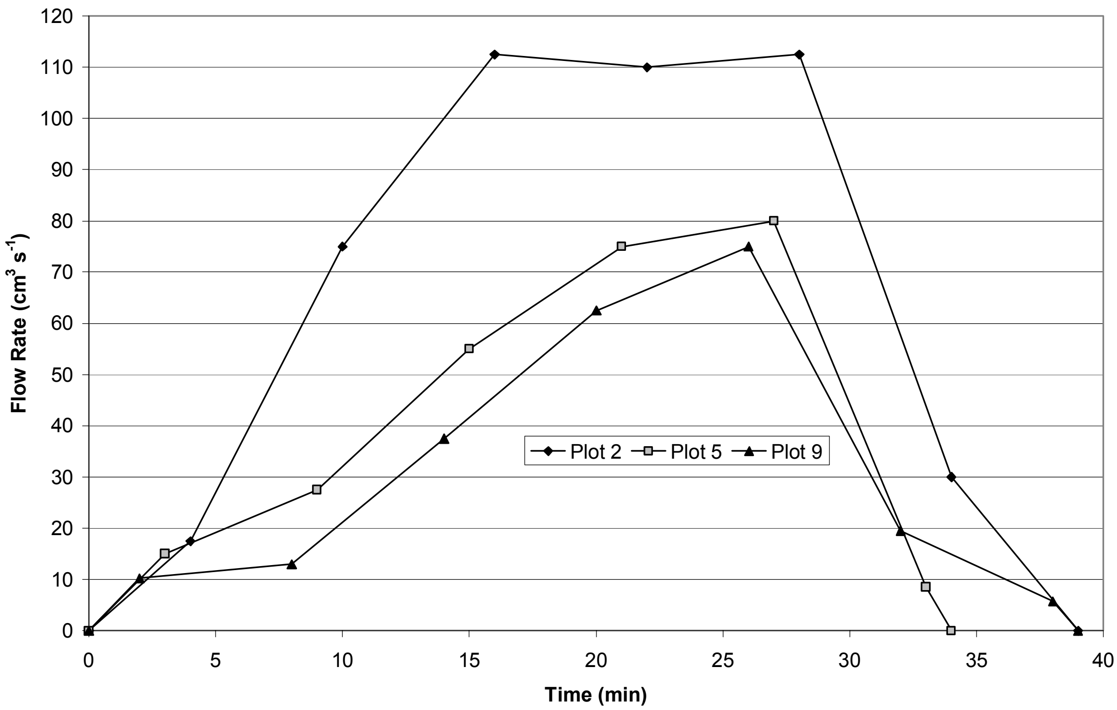

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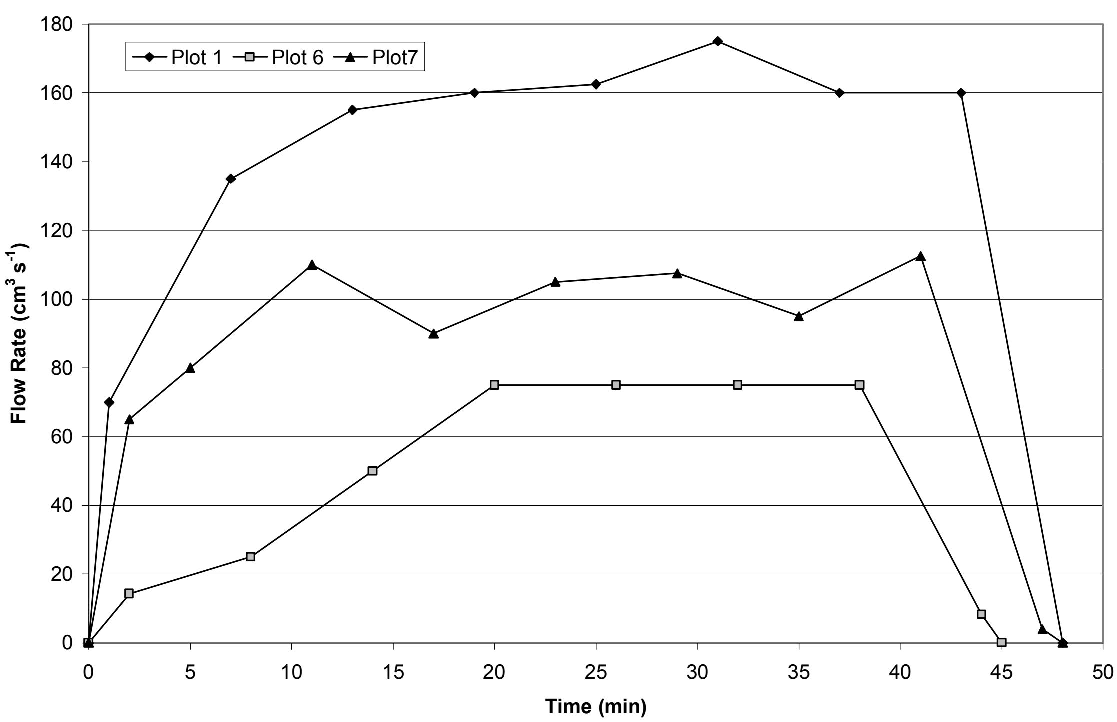

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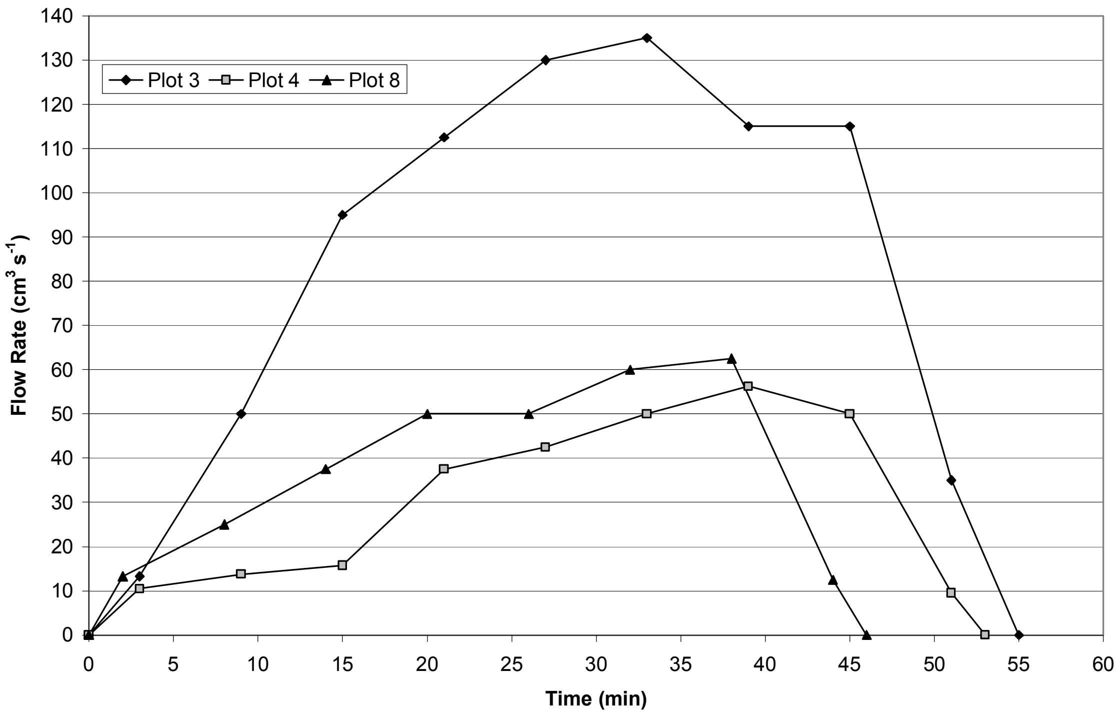
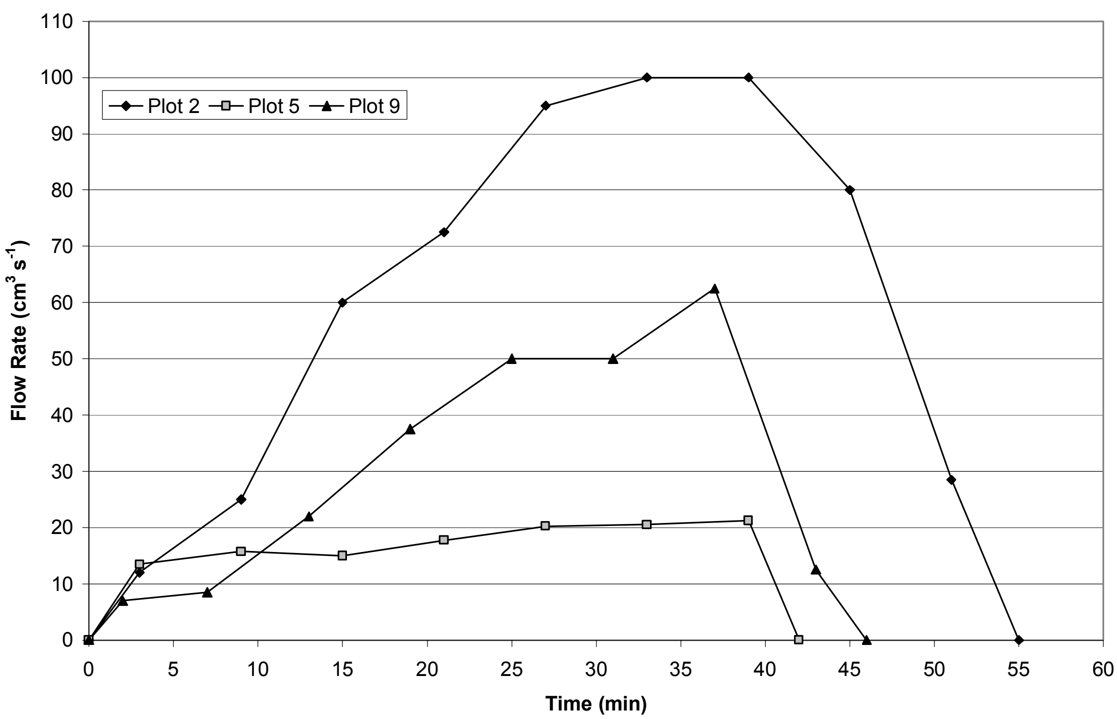
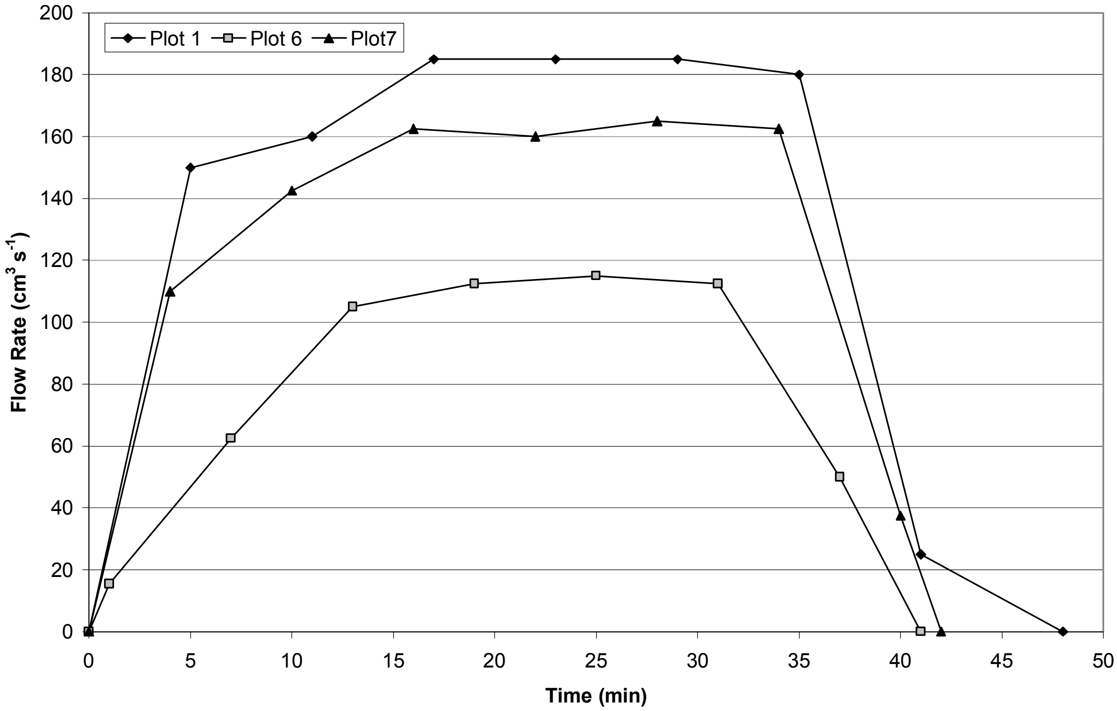


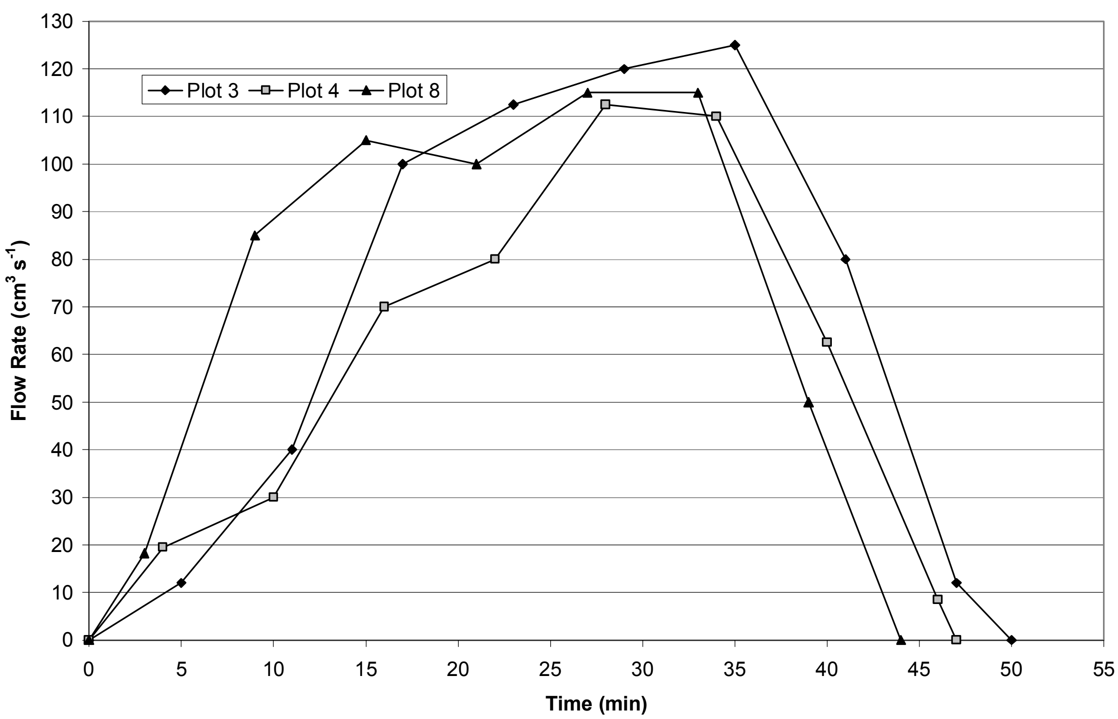
The July Run1 hydrographs for the strip tillage plots



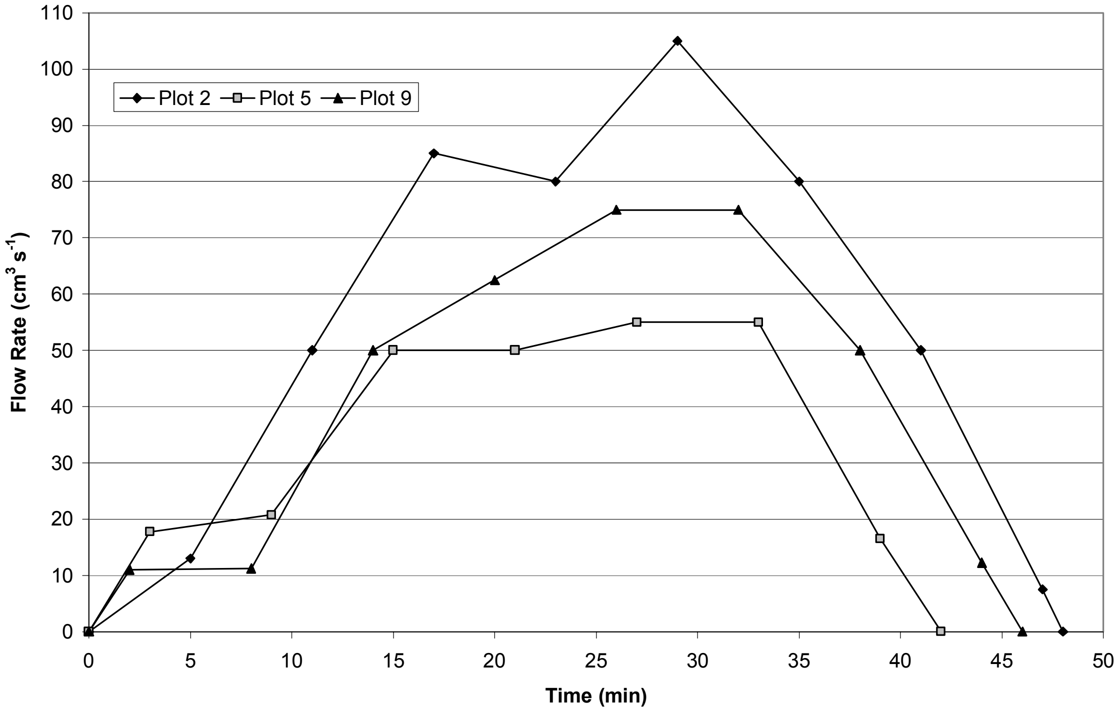
The July Run1 hydrographs for the no-till treatments



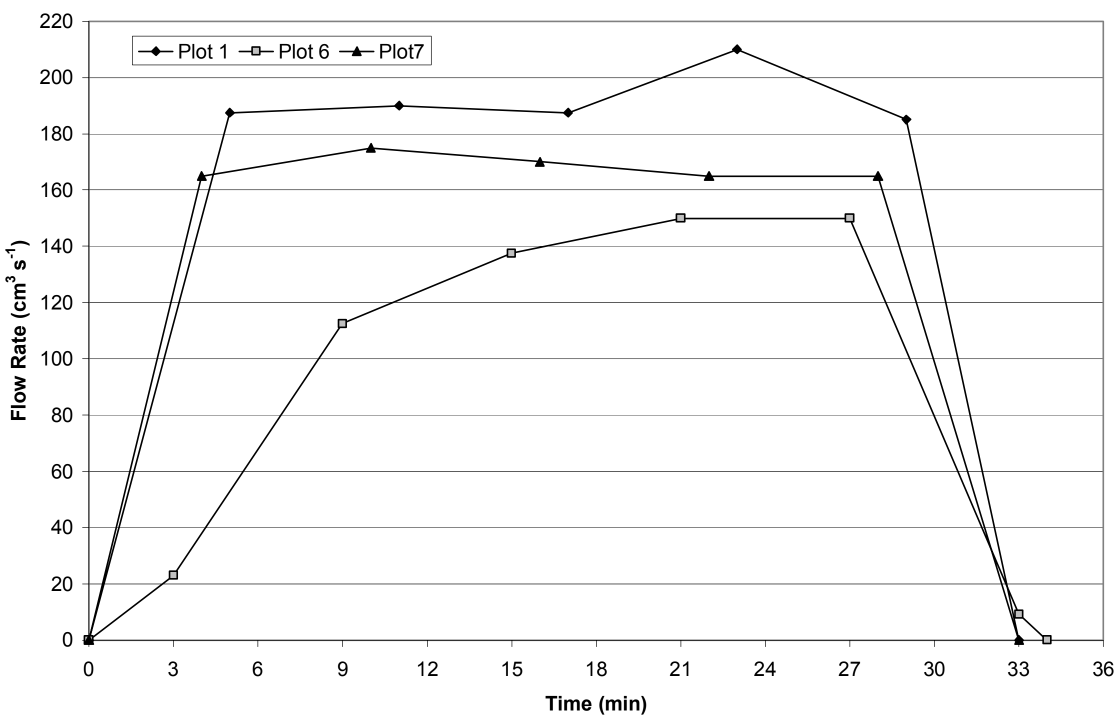
The July Run2 hydrographs for the conventional tillage plots



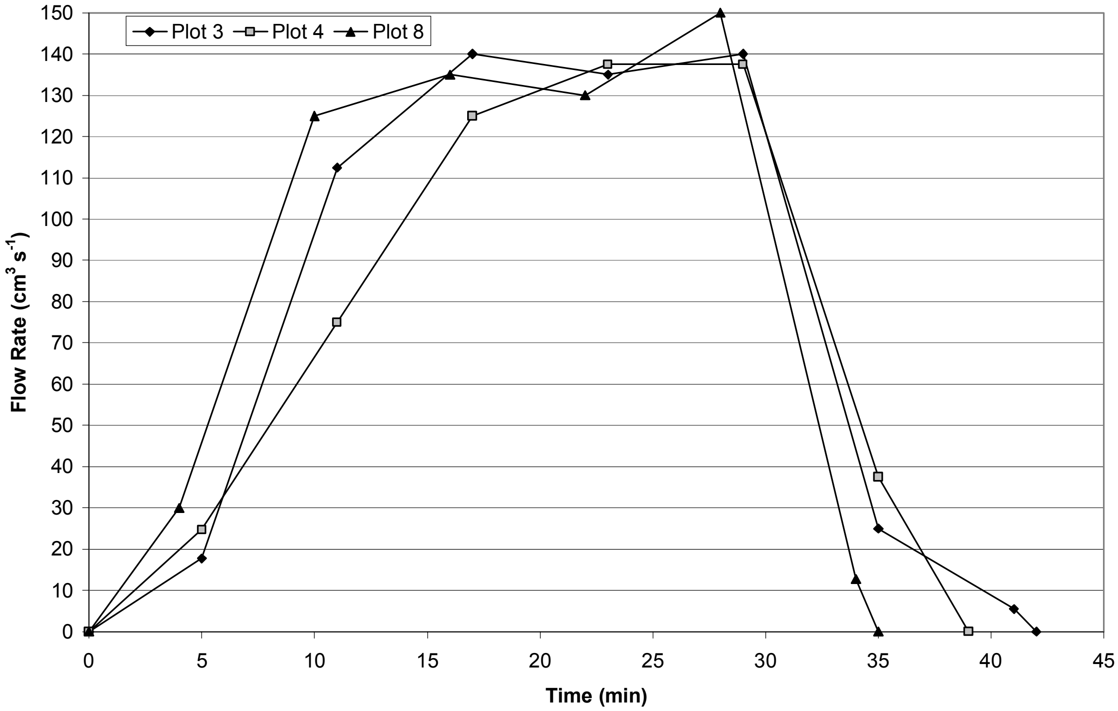
The July Run2 hydrographs for the strip tillage plots



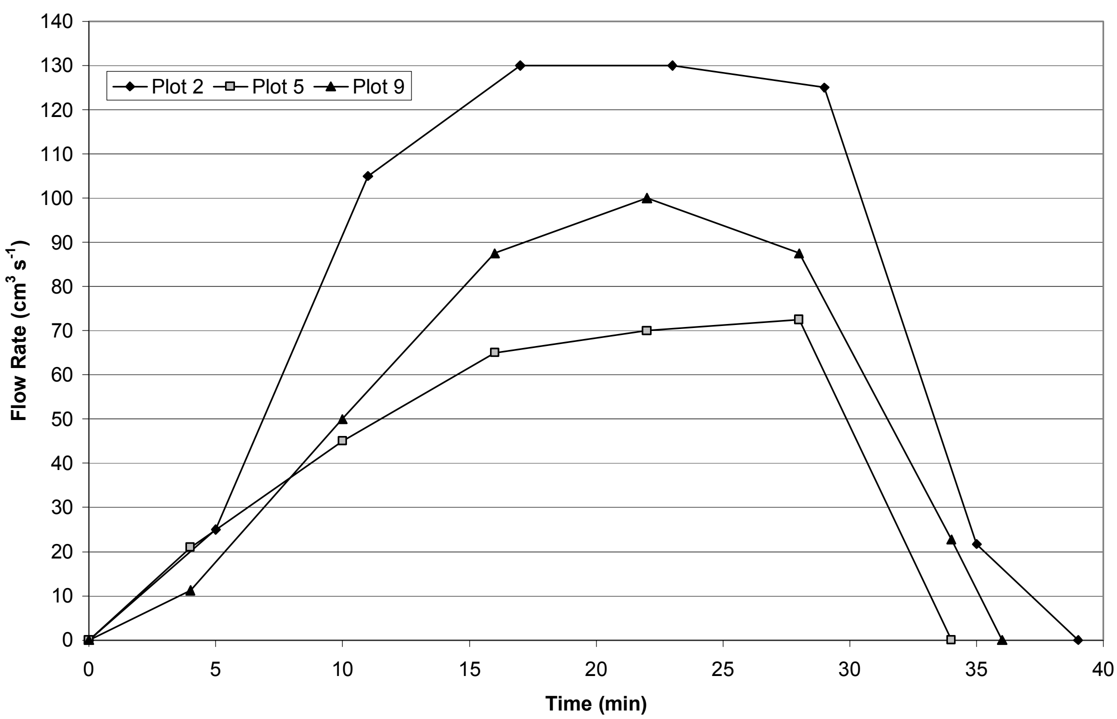
The July Run2 hydrographs for the no-till plots



The July Run3 hydrographs for the conventional tillage plots



The July Run3 hydrographs for the strip tillage plots



The July Run3 hydrographs for the no-till plots

Appendix B
Gas Chromatograph Specifications

Gas Chromotography Specifications for HP6890 μECD 350C

Section/Unique Setting	Description
Inlet	Splitless, 250C
Capillary Column	HP-5, 30 m*0.25 mm*0.25 um
Gas Rate	UHP Helium, 1.3 mL per min
Temperature Procedure	begin at 100C hold for 1 minute
	increase 10C per minute to 180C hold for 10 minutes
	increase 5C per minute to 275C hold for 2 minutes

Appendix C
SAS Statistical Code

Runoff Nutrient Concentration SAS code

```
proc import datafile=megan.work;
run;
proc sort;
by  Date Run;
proc glm;
by Date Run;
class Date Treatment Block;
model NO3conc NH3conc TKNconc PO4conc TPconc TSSconc = Treatment Block;
contrast "CT vs. ST and NT" Treatment 1 -0.5 -0.5;
contrast "NT vs. ST" Treatment 0 1 -1;
means Treatment/ LSD;
run; quit;
```

Runoff Nutrient Total Mass Loading SAS code

```
proc import datafile=runoffff.work;
run;
proc sort;
by  Date Run;
proc glm;
by Date Run;
class Date Treatment Block;
model VolumeL NO3 NH3 TKN PO4 TP TSS = Treatment Block;
contrast "CT vs. ST and NT" Treatment 1 -0.5 -0.5;
contrast "NT vs. ST" Treatment 0 1 -1;
means Treatment/ LSD;
run; quit;
```

Runoff Pesticide Concentration and Total Mass Loading SAS code

```
proc import datafile=ropest.work;
run;
proc sort;
by Date Run;
proc glm;
by Date Run;
class Treatment Block;
model chlorpyrifosConc PrimePlusConc Dbmg PPmg = Treatment Block;
run; quit;
```

Lysimeter Nutrient Concentration SAS code

```
proc import datafile=Lysnutrt.work;
run;
proc sort;
by Date;
proc glm;
by Date;
class Treatment Block;
model NO3Conc NH3Conc TKNConc PO4Conc TPConc TotalVolume NO3Mass NH3Mass TKNMass
PO4Mass TPMass = Treatment Block;
means Treatment/LSD;
run; quit;
```

Appendix D
GLEAMS Input Parameter Files

Conventional Tillage (CT) Hydrology Parameter File
2001-2050

4	2001000	1	0	1	1	0	0	1	0	0
6	7.25	.5	.05	3.5	82	.008	.792	18.0	2290.0	36.8792
7	2	1	18.0							
8	.51									
9	.2									
10	.07									
11	3.3									
12	2.5									
13	16.0									
14	20.0									
15	5.433									
16	28.0									
18	45.94	48.61	56.39	67.0	71.45	81.57	82.97	83.52	78.67	63.48
19	49.93	41.06								
20	28.55	27.54	35.1	46.2	48.0	59.41	63.28	60.96	58.44	49.23
21	35.9	29.39								
22	199.0	274.0	354.0	469.0	537.0	586.0	567.0	510.0	431.0	309.0
23	224.0	184.0								
24	184.8	206.4	180.0	180.0	156.0	146.4	134.4	122.4	115.2	105.6
25	189.6	199.2								
26	28.22	28.22	31.53	40.91	53.28	60.28	64.97	65.27	65.27	57.97
27	34.61	26.91								
28	2001	2050	2							
29	52	0277	1121							
30	0									
29	67	1144	1242			4.758				
30	0									
29	52	1277	2121							
30	0									
29	67	2144	2242			4.758				
30	0									
29	52	2277	3121							
30	0									
29	0									
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33	-1	0	0	0

Strip Tillage (ST) Hydrology Parameter File
GLEAMS Simulation 2001-2050

```
4     2001000    1    0    1    1    0    0    1    0    0
6       7.25    .5   .05   3.5    79   .008   .792   18.0  2290.0 36.8792
7         2     1   18.0
8       .51
9        .2
10      .07
11      3.3
12      2.7
13      16.0
14      20.0
15      5.433
16      28.0
18      45.94   48.61   56.39   67.0   71.45   81.57   82.97   83.52   78.67   63.48
19      49.93   41.06
20      28.55   27.54   35.1   46.2   48.0   59.41   63.28   60.96   58.44   49.23
21      35.9   29.39
22      199.0   274.0   354.0   469.0   537.0   586.0   567.0   510.0   431.0   309.0
23      224.0   184.0
24      184.8   206.4   180.0   180.0   156.0   146.4   134.4   122.4   115.2   105.6
25      189.6   199.2
26      28.22   28.22   31.53   40.91   53.28   60.28   64.97   65.27   65.27   57.97
27      34.61   26.91
28      2001   2050    2
29        52   0277   1121
30       0
29        67   1144   1242              4.758
30       0
29        52   1277   2121
30       0
29        67   2144   2242              4.758
30       0
29        52   2277   3121
30       0
29        0
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33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	-1	0	0	0

No-till (NT) Hydrology Parameter File
GLEAMS Simulation 2001-2050

```
4    2001000    1    0    1    1    0    0    1    0    0
6       7.25   .5   .05   3.5   76   .008   .792   18.0  2290.0 36.8792
7          2    1   18.0
8        .51
9         .2
10       .07
11       3.3
12       2.7
13      16.0
14      20.0
15     5.433
16      28.0
18     45.94  48.61  56.39  67.0  71.45  81.57  82.97  83.52  78.67  63.48
19     49.93  41.06
20     28.55  27.54  35.1  46.2  48.0  59.41  63.28  60.96  58.44  49.23
21      35.9  29.39
22     199.0  274.0  354.0  469.0  537.0  586.0  567.0  510.0  431.0  309.0
23     224.0  184.0
24     184.8  206.4  180.0  180.0  156.0  146.4  134.4  122.4  115.2  105.6
25     189.6  199.2
26     28.22  28.22  31.53  40.91  53.28  60.28  64.97  65.27  65.27  57.97
27     34.61  26.91
28      2001   2050      2
29        52   0277   1121
30        0
29        67   1144   1242          4.758
30        0
29        52   1277   2121
30        0
29        67   2144   2242          4.758
30        0
29        52   2277   3121
30        0
29        0
33        0    0    0    0
33        0    0    0    0
33        0    0    0    0
33        0    0    0    0
33        0    0    0    0
33        0    0    0    0
33        0    0    0    0
33        0    0    0    0
33        0    0    0    0
```

33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	0	0	0	0
33	-1	0	0	0

Conventional Tillage (CT) Erosion Parameter File
GLEAMS Simulation 2001-2050

4	2001	2050	4	1	0					
5	179.0									
6	1	7.25								
7	500.0	.008								
8	1	1.0	.2275							
13	2									
14	001	121	142	163	182	195	218	242	277	347
14	001	121	142	163	182	195	218	242	277	347
15	1	1.0								
16	.13	.2	.68	.60	.45	.30	.24	.13	.55	.17
17	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
18	.023	.0547	.014	.014	.014	.014	.014	.014	.014	.023
16	.13	.2	.68	.60	.45	.30	.24	.13	.55	.17
17	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
18	.023	.0547	.014	.014	.014	.014	.014	.014	.014	.023

Strip Tillage (ST) Erosion Parameter File
GLEAMS Simulation 2001-2050

4	2001	2050	4	1	0					
5	179.0									
6	1	7.25								
7	500.0	.008								
8	1	1.0	.2225							
13	2									
14	001	121	142	163	182	195	218	242	277	347
14	001	121	142	163	182	195	218	242	277	347
15	1	1.0								
16	.13	.2	.23	.22	.20	.17	.14	.13	.55	.17
17	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
18	.023	.0547	.0271	.0271	.0271	.0271	.0271	.014	.014	.023
16	.13	.2	.23	.22	.20	.17	.14	.13	.55	.17
17	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
18	.023	.0547	.0271	.0271	.0271	.0271	.0271	.014	.014	.023

No-till (NT) Erosion Parameter File
GLEAMS Simulation 2001-2050

4	2001	2050	4	1	0					
5	179.0									
6	1	7.25								
7	500.0	.008								
8	1	1.0	.2225							
13	2									
14	001	121	142	163	182	195	218	242	277	347
14	001	121	142	163	182	195	218	242	277	347
15	1	1.0								
16	.13	.2	.15	.15	.14	.13	.1	.13	.55	.17
17	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
18	.023	.0547	.0547	.0547	.0547	.0547	.0547	.014	.014	.023
16	.13	.2	.15	.15	.14	.13	.1	.13	.55	.17
17	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
18	.023	.0547	.0547	.0547	.0547	.0547	.0547	.014	.014	.023

Pesticide Parameter File Used for all tillage practices
GLEAMS Simulation 2001-2050

```
4        2001000 2050365     2     2     3     0
5            1       chlorpyrifos     0     0
5            2      PrimePlus     0     0
6            1    1.39    1.7  6070.0    0.0    .65          0.0
7          15.0    15.0    15.0    15.0    15.0    0.0    0.0    0.0    0.0    0.0
6            2     .1    7.0 10000.0    0.0    .4          0.0
7          20.0    20.0    20.0    20.0    20.0     .4     .1     .1    0.0    0.0
8          1140      1
9            1   2.242    1.0    0.0     .9     0
8          1205      1
9            2   1.345    1.0     .8     .1     0
8          2140      1
9            1   2.242    1.0    0.0     .9     0
8          2205      1
9            2   1.345    1.0     .8     .1     0
8            0
```

Conventional Tillage (CT) Nutrient Parameter File
GLEAMS Simulation 2001-2050

```
4        2001    2050     2     2     0
5        100.0    .24
6
7
8
9          0.0
10      .03561
11      9.6667
12         0.0
13        1001
14           0     0    1121
15          52     0
13        1139
14           1     5    1242
15          67     0
16        1140      0      1
17       224.0    0.0   134.0     8.8
19        1139     19    15.2
19        1140     10     8.8
19        1142     10     8.8
19        1160      6     8.8
19        1179      6     8.8
13        1275
14           0     1    2121
15          52     0
19        1275     19    15.2
13        2139
14           1     5    2242
15          67     0
16        2140      0      1
17       224.0    0.0   134.0     8.8
19        2139     19    15.2
19        2140     10     8.8
19        2142     10     8.8
19        2160      6     8.8
19        2179      6     8.8
13        2275
14           0     1    3121
15          52     0
19        2275     19    15.2
13           0
```

Strip Tillage (ST) Nutrient Parameter File
GLEAMS Simulation 2001-2050

4	2001	2050	2	2	0
5	100.0	.24			
6					
7					
8					
9	0.0				
10	.03516				
11	9.6667				
12	0.0				
13	1001				
14	0	0	1121		
15	52	0			
13	1140				
14	1	1	1242		
15	67	0			
16	1140	0	0		
17	224.0	0.0	134.0	0.0	
19	1142	21	8.8		
13	1275				
14	0	1	2121		
15	52	0			
19	1275	19	15.2		
13	2140				
14	1	1	2242		
15	67	0			
16	2140	0	1		
17	224.0	0.0	134.0	0.0	
19	2142	21	8.8		
13	2275				
14	0	1	3121		
15	52	0			
19	2275	19	15.2		
13	0				

No-till (NT) Nutrient Parameter File
GLEAMS Simulation 2001-2050

4	2001	2050	3	2	0
5	100.0	.24			
6					
7					
8					
9	0.0				
10	.03516				
11	9.6667				
12	0.0				
13	1001				
14	0	0	1121		
15	52	0			
13	1140				
14	1	0	1242		
15	67	0			
16	1140	0	0		
17	224.0	0.0	134.0	0.0	
13	1275				
14	0	1	2121		
15	52	0			
19	1275	19	15.2		
13	2140				
14	1	0	2242		
15	67				
16	2140	0	0		
17	224.0	0.0	134.0	0.0	
13	2275				
14	0	1	3121		
15	52				
19	2275	19	15.2		
13	0				